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FY 1978 AERONAUTICS AND SPACE TECHNOLOGY
PROGRAM SUMMARY

Office of Aeronautics and Space Technology
National Aeronautics and Space Administration

Statement

Before the

Committee on Commerce, Science, and Transportation
United States Senate

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SECTION I-A. INTRODUCTION

In addition to the regular Office of Aeronautics and Space Technology (OAST) planning process and special NASA studies such as the Outlook for Aeronautics, the background for our proposed FY 1978 Aeronautics program includes a number of recommendations contained in a September 1976 report of the Senate Committee on Aeronautical and Space Sciences. Our program and our long-range planning are essentially responsive to these recommendations.

It was recommended, for example, that NASA initiate a long-term program to revitalize the R&T Base, with particular emphasis on the maintenance of in-house capability, and that we undertake the advanced high-risk research and technology that industry cannot afford to support. Our FY 1978 program includes a 10 percent increase in the R&T Base -- a significant growth considering the fact that the high-priority Aircraft Energy Efficiency (ACEE) program is approaching its peak funding requirement at the same time. We have initiated an intensive assessment of the base programs, and the Aeronautics and Space Engineering Board of the National Research Council also is performing an independent assessment to further evaluate the quality and adequacy of the program and the balance between in-house and contracted activity. By its very long-lead nature and the inability to guarantee successful application, much of the base program does in fact constitute the high-risk effort which is beyond industry's ability to support.

The Senate staff report also recommended responsiveness to national needs through pursuit of technology applications permitting the incorporation of necessary advances in new aircraft with reduced technological and financial risk. Our proposed program is in consonance with this recommendation, both in a general sense and with respect to the specific areas cited by the Committee staff for particular attention. The specific measures recommended and addressed in the FY 1978 program include: the efforts in turboprop technology, laminar flow control, and alternative fuels in the energy efficiency and propulsion research areas; focused research on noise abatement and engine exhaust emissions reduction; expanded safety research with increased emphasis on general aviation; accelerated preparation of supersonic cruise technology with primary concentration on the critical issue of variable cycle engine technology; and research on the problems of agricultural aircraft technology.

In regard to more advanced potential future developments such as vertical/short-takeoff-and-landing (V/STOL) and hypersonic aircraft, the staff report recommended recognition of "national needs" in transportation as an aid to establishment of research priorities. We recognize that the application of these advanced aircraft classes as transportation vehicles is definitely farther out in time than the more conventional types. However, since NASA is responsible for new technology in support of both civil and military aviation, the program includes continuing research in these areas in view of the probable nearer term military importance as well as the eventual civil potential.

A summary of the proposed NASA FY 1978 Aeronautics program is presented in Section I-B, and Sections I-C and I-D describe the proposed activities in Aircraft Energy Efficiency technology and Supersonic Cruise Aircraft Research (SCAR), respectively, in more detail.

SECTION I-B. FY 1978 PROGRAM SUMMARY

The FY 1978 Aeronautics research and technology budget request is \$231 million (Figure 1), an increase of 22 percent relative to FY 1977. The increase is made up of an \$8.5 million increment to the R&T Base, which generates advances in the primary technical disciplines and thus provides the foundation for both ongoing and future programs, and a \$32.4 million buildup in Systems Technology and Experimental Programs, in which technology advances are carried toward the point where they can be applied in actual development. While responsive to the need for constraints on Government expenditures, this budget is designed to assure continued progress in FY 1978 in each of the program areas selected for emphasis, and in the continued R&T Base preparation for more advanced programs in the future.

In the following statement, the proposed FY 1978 NASA Aeronautics Program is presented in terms of highlights from the Systems Technology and Experimental Programs being conducted in the major areas identified in the NASA planning activities (Figure 2). Certain elements of the work will be presented under the headings of Generic Technology and R&T Base which include some other important systems technology activities and significant research which is more basic and not specifically directed toward particular applications. Proposed activities in Aircraft Energy Efficiency and Variable Cycle Engine-Supersonic Cruise Aircraft Research are presented separately in Sections I-C and I-D, respectively.

In Helicopter/VTOL technology two major joint Army/NASA research programs are nearing the important flight testing phase. October 1976 saw both the first flight of the Rotor Systems Research Aircraft (RSRA) (Figure 3) and the roll-out of the first Tilt Rotor Research Aircraft (TRRA) (Figure 4).

In order to improve the effectiveness of our helicopter research, the Ames Research Center has been designated our lead Center for helicopter technology activities. Research objectives are aimed at continuing advancement in helicopter performance, vibration and dynamics, noise and flying qualities.

The RSRA will be utilized in advanced rotor research (Figure 5) as a flight research facility which is the

culmination of the research activities carried on in ground laboratory facilities and in preliminary flight experiments. Small-scale tests in wind tunnels (upper left, Figure 5) will evaluate rotor aerodynamics and advanced hub concepts; large-scale or full-scale tunnel tests (lower left) will follow for rotor concepts which show promise in the small-scale tests; flight tests of advanced rotor airfoils on the AH-1G "Cobra" Research Helicopter (lower right) will be completed in FY 1977. RSRA flight tests (upper right) will continue into FY 1978. They will be conducted with the initial rotors and in both the basic helicopter configuration shown and a compound configuration with wings and jet engines. Objectives include vehicle flight envelope expansion and investigations of handling qualities and other flight characteristics--some of which are possible only with a flight research facility such as the RSRA which permits us to isolate the rotor for research measurement and to operate over a broad range of rotor loadings by transferring load from the rotor to the wings. Future flight research on the RSRA will evaluate advanced rotors and control concepts now being explored in the R&T Base program. The two RSRA vehicles are scheduled to be delivered to the Ames Research Center in late FY 1978 following their contractor flightworthiness testing.

In the rotorcraft technology area, technology for Helicopter transmissions will be emphasized. The objective is to bring several advanced transmission components, which have reached individual technology readiness, into a state of integrated system technology readiness. The program goal is to establish a high level of confidence in the use of advanced mechanical components in civil and military helicopter transmissions and similar applications so that major reductions in maintenance can be realized (Figure 6). The program goal is 2,500 hours between overhauls, compared with about 700 hours today.

In FY 1978 transmission system designs will be started, accompanied by some component testing--primarily bearings and gearing. Greater durability is sought in the bearings, and higher load capacity for a given size is expected in the gearing. Also being evaluated is a traction-drive speed reduction system which could exceed the capability of conventional gearing in terms of speed reduction, low noise and long life.

In the Tilt Rotor Research Program flight tests will get under way with a pair of research vehicles (Figure 4).

Proof-of-concept flight tests will start in FY 1978, following full-scale tests in the Ames 40-by-80 foot wind tunnel. The objectives of the flight tests will be to explore the vehicles' operating envelope and to evaluate their performance, dynamic stability, handling qualities and terminal operations. By being able to operate the rotors both in this vertical-lift position (Figure 4) and in a forward-thrust, propeller-like position in flight, a tilt rotor aircraft attains the hovering characteristics of a conventional helicopter with about twice the cruise speed.

The technology of higher performance VTOL aircraft will be advanced through continuation of the aerodynamic and flight dynamic R&T Base activities. Both low- and high-speed wind-tunnel tests will be conducted with powered models. The Ames flight simulators and advanced analytical programs will also be used to improve the prediction of performance and flying qualities. NASA activities in VTOL technology will be closely coordinated with Navy needs and R&D programs.

Another type of VTOL flight system receiving attention is the heavy-lift airship (Figure 7). Buoyant and rotor lift are combined in a hybrid vehicle predicted to be capable of precision vertical lift and placement of heavy, outsized loads. Potential military uses include ship off-loading, as in an emergency when port facilities are damaged or inadequate. Civil uses include transportation of power plant or reactor components, placement of assembled oil-rig or transmission towers, and short-haul cargo movement in regions with inadequate ground transportation. Availability of this postulated heavy-lift capability could lead to significant changes in several major industries and their design and fabrication processes. After several years of study, and in cooperation with the U. S. Navy and Army, NASA expects to initiate basic technology activities in FY 1978 in areas such as stability and control, aerodynamics and structures.

The next FY 1978 highlight area is General Aviation. This broadly based R&T program, which has been strengthened with Congressional encouragement and support, is now showing visible results in production aircraft (Figure 8). Activities continue in crash-worthiness, noise and emission reduction, drag reduction, interior noise reduction, and integrated avionics systems. The FY 1978 program (Figure 9) will highlight: airfoil development with emphasis on medium-speed (300-500 mph)

applications on high-performance, single- and twin-engine turboprop aircraft; stall-spin research, in which the effort will be accelerated and expanded to include full-scale testing with high-wing, low-wing and twin-engine aircraft; low-cost avionics, particularly in navigation equipment and cockpit displays; and propulsion, including component testing and assembly of the Quiet, Clean General Aviation Turbofan (QCGAT) experimental engines and the advancement of propeller technology using new materials, airfoil sections and controls.

A closely related technology area which has received considerable recent attention is that of aerial applications, or agricultural aviation. This is a difficult area to assess because of the diversity of operations and multitude of manufacturers and users. Extensive NASA contacts with people and organizations in this field, including three NASA-sponsored workshops, have pointed to critical needs and high potential benefits. Program definition is under way in FY 1977 by means of system studies and preliminary experimental evaluations. The objective is to aid NASA management in its determination of a proper NASA role and level of involvement. During FY 1978, investigations are planned in four principal technology areas (Figure 10): improved aircraft characteristics, flow-field modification, integrated dispersal equipment, and specialized measurement systems. We are identifying the major requirements and limiting factors in aerial applications and will then develop the technology to apply the materials, liquid or dry, precisely where they are needed and in controlled quantities. These efforts thus far, and complementary programs by EPA, USDA and FAA, show that significant improvements can be achieved.

In response to recommendations by the GAO as a result of its review of the Federal activity on Short-Haul STOL Aircraft, NASA has reassessed the technical content, scale, and pace of its STOL technology program. The reassessment included reviews in depth with the DOT, the FAA, and the DOD, and emphasized the relationship between NASA's activities and those of other interested agencies. Recognizing that NASA's concern is the long-lead technology which is required to provide options for advanced short-haul systems in the future, and recognizing also that the propulsive-lift technology has potential application to conventional as well as STOL aircraft, it was generally agreed that the program is appropriate, necessary, and timely. NASA will continue to coordinate and evaluate

its program with these agencies and with industry in the context of evolving civil and military plans for applying STOL technology.

The current program to advance the technology of short-haul transports, with emphasis on quiet propulsive lift for short-takeoff-and-landing (STOL) aircraft, is chiefly comprised of the Quiet Short-Haul Research Aircraft (QSRA) project, NASA participation in the USAF flight tests of the Advanced Medium STOL Transport (AMST) prototype aircraft, the Quiet, Clean Short-Haul Experimental Engine (QCSEE) Program, and the STOL Operating Systems Experiments Program. Flight research on QSRA (Figure 11) is scheduled to begin in FY 1978. A C-8A Buffalo aircraft is currently undergoing modifications (see insert, Figure 11) to receive the new wing and engines, and will be out of the Boeing shop in about a year.

The QSRA is a research aircraft designed to permit flight investigations over a range of conditions beyond the capabilities of an AMST which, as a military pre-production prototype, is necessarily a point design. The QSRA is also designed to allow flight research specifically addressed to future civil applications, including broad and flexible exploration of operational boundaries, safety margins, and noise characteristics of a high propulsive-lift configuration. Such data are necessary for civil certification of STOL transports. Wind tunnel tests of one-sixth and one-half scale models have been completed, showing satisfactory flap/nozzle flow turning and providing essential design data on flow interactions, aerodynamic performance, air loads, and stability and control coefficients.

While an AMST (Figure 12) is less versatile as a flight research facility, it provides a very useful adjunct to the QSRA with the advantage of earlier flight availability. NASA's participation in the USAF's AMST flight test program is an opportunity to obtain necessary STOL data and correlate flight, simulator and wind-tunnel test data. Although NASA's part in the prototype test and evaluation program was on a limited, noninterference basis, valuable research data have been obtained. In FY 1978, during the AMST development phase, NASA will have additional opportunity to measure research data relative to a wide variety of STOL aircraft characteristics throughout the range of operating conditions. These flight data will be used to correlate theory,

wind-tunnel model data and test-rig data to improve our understanding of propulsive-lift STOL transport aircraft.

NASA's Quiet, Clean Short-Haul Experimental Engine (QCSEE) Program (Figure 13) is designed to provide advanced propulsion system technology applicable to future STOL transport aircraft. QCSEE objectives include major noise reduction and the demonstration of several advanced technology propulsion innovations, such as the acoustically-designed, all-composite, structurally-integrated nacelle. The noise goal is a 90 EPNdB footprint area of under one square mile (compared to 4-5 square miles for the YC-14 AMST). Test results through CY 1976 from inlet/nozzle-model and initial full-scale engine tests (Figure 13) provide high confidence that program objectives will be met. The QCSEE program is scheduled to be completed in FY 1978.

In addition to these highlight theme areas, in which NASA aeronautical technology activities are focused on specific aviation needs and systems, a substantial portion of the NASA FY 1978 technology activity will be generic, or related to other potential applications or broad problem areas. One such activity is that of configuration research aimed at the improvement of military combat aircraft (Figure 14). Using wind tunnels, remotely-piloted research vehicles (RPRV) and full-scale military aircraft, NASA is carrying out a coordinated program of configuration research. The objectives include maneuverability enhancement through the use of canards, strakes, blowing and thrust vectoring, as well as improved propulsion integration with two-dimensional nozzles. Proof-of-concept flight tests follow for the most promising technologies. The HiMAT program (Figure 15) will provide a remotely-piloted flight research facility for safe and economical integration and demonstration of advanced configuration features, serving to verify wind-tunnel and analytical data, and making the combined use of these research tools more effective. These methods, used in a unique interactive fashion, have resulted in a configuration which should provide a 100 percent increase in aerodynamic efficiency at high lift. That is, compared to current and emerging maneuverable aircraft, the HiMAT vehicle should be capable of twice the 'g' loads. In FY 1978, fabrication of the HiMAT research vehicle will be completed and the flight research program will begin.

*HiMAT -- Highly Maneuverable Aircraft Technology

studies to determine the advantages and disadvantages of the device in conditions as close to operational realism as possible. Investigations in the flight management area are continuing to assess factors affecting human performance in the cockpit. This human factors research investigates the complex interactions among crew members, aircraft, and the air traffic system, using flight simulation to represent operational conditions. Specific emphasis is on developing means to enhance crew coordination.

Another broadly applicable Systems Technology project is IPAD (Figure 17), which stands for Integrated Programs for Aerospace Vehicle Design and is the development of a computerized system to support the design process for complex aerospace vehicles. The objective is to reduce significantly the cost and time required for vehicle design; the program goals are reductions of 25 percent in cost and 50 percent in time. As illustrated, a design team would operate with interactive facilities, each member having a specific responsibility but working together in real time through the computer. Console displays and controls would permit ready modification of technical and management information in graphical and textual format, interactive communication among users, and on-line manipulation of codes, data and other design information. The first release of IPAD for evaluation purposes is scheduled for June 1978. Feedback from users will lead to an updated capability in mid-1979 and a general IPAD release in the Fall of 1980. This project is proceeding with strong support and interaction with the potential users in the aerospace industry.

In the Materials and Structures area, the use of composites is projected in just about every advanced vehicle system concept. As a complement to the primary structures activity in the ACEE Program, NASA has begun a technology effort focused on composites durability. The objective is to provide the statistically valid quantitative information necessary for a high degree of confidence in prediction of durability and integrity of composite structures. The effort in FY 1978 extends the R&T Base work on laboratory specimens to subcomponent tests under combined loading. Techniques of damage detection and quality control will also be investigated, leading to extensive statistical data on life prediction and environmental effects, and to continued extension of service life.

The Digital Fly-By-Wire Program involves flight research and technology demonstration on a triplex digital fly-by-wire flight control system. In FY 1978, NASA will be conducting an average of two flights per month to complete the evaluation of advanced transport control laws in a representative environment, leading to a design base in FY 1979.

The Stratospheric Cruise Emissions Reduction Program (SCERP) was begun in FY 1977 (Figure 18). The objective of the SCERP Program is to demonstrate advanced combustor technology which could enable significant reductions in nitrous-oxides (NO_x) emissions of future subsonic aircraft during high-altitude cruise operations. The SCERP emissions index target is set at or below the recommendation of the Climatic Impact Assessment Program (CIAP). Contracts have been let for the initial part of the program, in which advanced combustor and fuel preparation concepts will enter hardware phases during FY 1978.

The foregoing discussion of technology programs and highlight areas illustrates how concepts and technology applications are carried forward toward eventual readiness for operational use. Before reaching Experimental Program or Systems Technology status, they all had their beginnings in the R&T Base Program. Accounting for nearly one-half of the OAST program budget and engaging the majority of aeronautics Research Center personnel, the R&T Base continues to be an active source of new technology in each of the aeronautical disciplines. The program contains far too many items to permit even an attempt at full coverage. However, the following cites some examples which illustrate representative segments of the NASA FY 1978 R&T Base activity.

Two examples in the high-temperature materials area are: (1) a process for applying thermal barrier coatings to metallic turbine blades and (2) recent progress in the design of ceramic turbine blades. The Lewis Research Center has developed the coating process (Figure 19), in which two layers are applied--an inner, metallic layer for compatibility with the substrate, and an outer layer of insulating oxide. This coating reduces the temperature of the metal turbine blade 200°F below the outer surface temperature. Operation at the allowable higher inlet temperature would substantially increase jet engine efficiency and reduce operating cost accordingly. Oxidation and erosion would also be reduced. In FY 1978, turbine wheels with coated blades (the light-colored blades in the photo) will be tested in full-scale engines, and the method of application will be automated.

The second materials example is ceramic turbine blades. Ceramics have long been of interest as high-temperature materials for gas turbine applications. Compared to state-of-the-art superalloys, ceramics have the potential of operating at higher temperatures with superior corrosion resistance. They may also be much less costly and use nonstrategic materials. The major problem with ceramics, however, is their brittleness. This shortcoming may often times be avoided through careful design. The Lewis Research Center recently made significant progress in this area by successfully testing a new ceramic turbine blade and root design for use in a metal disc (Figure 20). This design was successfully tested at 2200°F for 100 thirty-minute cycles (50 hours). In FY 1978 additional testing will be conducted and necessary design changes will be incorporated to approach more nearly the high-temperature potential of ceramics. Incidentally, this technology is currently being applied to the design of a Navy marine turbine and an ERDA automotive turbine.

Another application for ceramics in gas turbines has to do with minimizing the loss of gas turbine efficiency by improved seals (Figure 21). The gap between the shroud or seal that encases the turbine wheel normally increases with operating time due to the oxidation of the shroud and the occasional rubbing of the blades against the shroud. An increase of 0.010-inch in clearance results in about one percent loss of turbine efficiency. The Lewis Research Center has sponsored the development of ceramic abradable seals that are much more resistant to oxidation and erosion than metallic seals. Recent results show that abradable ceramic seals offer the potential of uncooled operation at turbine temperatures at which metallic seals suffer significant inefficiencies due to cooling air flow requirements. For example, the two percent improvement in fuel consumption (Figure 21) if applied to the 747 fleet, would save 15 million gallons of fuel per year. Research efforts in FY 1978 will be aimed at optimizing the abradable characteristics of ceramic seals and increasing their high-temperature resistance to 2500°F.

Research is also being conducted to enhance the fire resistance of aircraft interiors. Whereas, in other R&T activities we seek ways of preventing fire, in this activity we are concerned with slowing the spread of fire across and through materials in the cabin and unattended areas such as cargo bays. The results of

the research will be materials with much improved overall fire resistance (Figure 22) in terms of ignition temperature, flame spread and toxicity. NASA is preparing to test nine different panels representing the best materials now commercially available and advanced materials which will become available in the near future. Tests have begun on one panel. Further testing in FY 1977 is expected to show that this panel is a 100 percent improvement over current materials. In FY 1978 we will complete the testing of all nine developmental panels. An estimate of the improvement that can be expected for panel materials in terms of controlling ignition, flame spread and flash-over is a total fire resistance some 4 to 5 times that of currently used materials. These efforts, along with complementary research on fire characterization and related systems technology testing in the Fire Resistant Materials Engineering Program, are expected to result in improved technological options for cabin design and fire control.

In the area of aircraft structures, the NASA research on aeroelasticity is aimed at developing the capability to predict and avoid wing flutter. Flutter is due to interactions between unsteady aerodynamic loading and structural response. Success in this effort will pay off through increased maneuver performance, payload, range and energy efficiency. Prediction methods have developed into integrated programs which can be used to predict both flutter boundaries of aircraft and their response to external disturbances such as gusts and turbulence. Simultaneously, techniques for the avoidance of flutter and minimization of aircraft response--especially active control technology and passive control via aeroelastic tailoring of control surfaces--using correlations of analytical, wind-tunnel and flight-test data have been conceived and evaluated. One such program (Figure 23) involves the use of the Navy FIREBEE II Drone as a remotely piloted research vehicle (RPRV). The use of an RPRV permits investigation of flight regimes which could not be explored with manned vehicles. The vehicle has been modified to accept a variety of wing planforms, including research wings designed to flutter within the vehicle's flight envelope. The first flight tests of such a research wing will be conducted in FY 1978. During these tests the vehicle will be flown beyond the flutter boundary (in the cross-hatched region on the altitude-speed plot), both with and without active controls.

Several times in preceding discussions the use of advanced analytical tools has been mentioned. An example of NASA's efforts to extend computational aerodynamics capabilities, as a low-cost adjunct of wind-tunnel and flight testing, is an attempt to exploit recent advances in the disciplines of computer science and fluid mechanics. NASA is currently in the process of defining a special facility--an optimized fluid dynamics processor--to provide numerical flow simulations at processing speeds some four orders of magnitude faster than now possible with the world's fastest multipurpose computer, the ILLIAC IV. Definition of the processor will continue in FY 1978.

In the area of aircraft noise and exhaust emissions, the NASA research programs will continue to expand the basic understanding of the phenomena associated with the generation, propagation, prediction and reduction of both noise and exhaust pollution emissions. Work is underway to explore the feasibility and effectiveness of attractive concepts for noise and pollution reduction in realistic applications. The FY 1978 efforts will include wind-tunnel and flight tests to improve the capability to predict accurately flight noise from ground static measurements. Techniques and concepts for reducing piston engine emissions for general aviation will also be examined.

The research and technology efforts in propulsion components will continue to emphasize energy conservation. Fan and compressor research will explore the limits of pressure ratio obtainable from high-performance compressor stages without sacrificing efficiency. The combustor and turbine R&T programs will be directed toward resolving the problems of operating at the high pressures and temperatures identified with energy efficient engines. In the engine drive system component research area, efforts will be focused on improving high-speed, highly loaded gears, seals, shafts and bearings.

Another potentially fruitful area of propulsion research is concerned with the integration of engines and airframes (Figure 24). For example, current nozzle installations in high-performance aircraft often result in excessive boat tail drag. Nonaxisymmetric nozzles, generally two-dimensional in configuration, offer significant drag reduction and other advantages such as the ability to vector thrust for maneuverability and safety and improvements in mechanical reliability,

cost and service life. The research effort involves detailed flow analyses, conceptual design studies and the development of methods for predicting overall installation effectiveness.

Another example of the diverse but essential nature of our R&T Base program is that of alternate fuels research. NASA activities with respect to alternate hydrocarbon fuels are conducted in close cooperation with corresponding DOD, ERDA and FAA investigations. The FY 1978 effort will continue the testing of broadened fuel specifications for fuel use flexibility. Both petroleum-based fuels and those which in the future will be refined from shale or coal will be included. Engine compatibility with these fuels will be investigated through assessments of "hot section" durability, fuel system materials behavior, and exhaust emissions, leading to design criteria for both existing and future energy efficient aircraft and engines.

The aim of NASA research in aircraft operating problem areas and aviation safety is to provide a technological basis for eliminating or avoiding serious hazards of the operational environment. In one such activity (Figure 25), and in cooperation with other agencies, work is in progress to increase the understanding of atmospheric processes, including severe turbulence and wind shear. The FY 1978 effort will include development of measurement techniques and simulation capabilities, tools with which operational procedures for coping with these anomalies can be perfected. Work is also in progress to improve safety in the ground-run phase of takeoff and landing (Figure 26), chiefly through (1) the use of a moving-base simulator for investigating directional control problems on the runway, (2) experiments with crosswind landing gear and (3) improvements in aircraft tire tread materials. This research is carried out with unique facilities and equipment designed to extend the limits of testing and understanding beyond what is usually attainable with exploratory and developmental flight testing.

A last example of R&T Base activity (Figure 27) is in avionics, in which a recent review of future directions has led to redefinition of emphasis on three electronics technology drivers: digital operations, integrated control and cockpit avionics. The aim of digital operations technology (Figure 28) is low-cost aircraft navigation and digital communications to permit all-

weather operations and minimal fuel consumption. This would be achieved through advanced onboard systems and data links that can be used with the DOD satellite Global Positioning System (GPS) to provide air route traffic control, precision navigation, collision warning, and automated weather, route and status reporting. Potential benefits include both reduced costs of onboard systems and ground operations and greatly improved safety and efficiency of aircraft flight operations. For example, the cost of onboard equipment compatible with the GPS could be as low as \$50,000 for a transport and \$5,000 for a light aircraft. FY 1978 efforts will consist of preliminary design studies to define aircraft navigation equipment and coding requirements to interface with GPS and to explore the potential of the digital data link.

The second new direction in avionics R&T, integrated control (Figure 29), concentrates on the integration of airframe, propulsion and subsystem control to enhance the efficiency and economics of future aircraft. Functions which are independent on current aircraft (such as fuel management, airframe control, propulsion control and landing loads control) will be combined both operationally and through the use of multipurpose hardware. The results should be improved control, reduced aircraft weight and fuel consumption, fewer black boxes, and reduced maintenance--all achieved with greater reliability. The potential reduction in black boxes is significant: from 64 to 20 in a B-737 class aircraft. The FY 1978 objective is to develop the conceptual specifications for such integrated control functions and systems.

Our work in cockpit avionics (Figure 30) focuses on the incorporation of advanced technology into the cockpit to optimize pilot workload and improve safety. More than 100 cockpit displays and controls are now required for operation of a typical transport. The development of advanced multipurpose displays and microprocessor-implemented mode controls for the various flight regimes could significantly simplify the pilot's tasks, as well as reduce avionics costs by better than 25 percent. Early elements of this program, to be initiated in FY 1978, will include the design and development of a multipurpose liquid-crystal-device display in a joint effort with the Air Force. Related efforts will address information input/output technology and design of alternate overall cockpit configurations. Later operational evaluations would be planned in the B-737 research cockpit.

The FY 1978 program described in this section and in the sections on Aircraft Energy Efficiency and Supersonic Cruise Aircraft Research is the result of considerable planning activity during which each of the program areas was examined to define, initially without regard to cost, desirable research and technology activities. These potential activities were then reviewed, integrated, and scaled down to reflect realistic budget considerations.

In one significant action, the NASA approach to vertical-takeoff-and-landing (VTOL) flight research was revised. Originally, the NASA plan had considered a joint Navy/NASA lift-cruise fan VTOL research aircraft project, coordinated with the Navy's development and testing of a multipurpose V/STOL prototype. As the Navy's prototype planning evolved, it became apparent that a single combined program would be a more efficient approach to satisfying both the flight research and the military prototype objectives. Under the new plan, NASA will provide research and technology support to the Navy, and the prototype design will be modified for increased versatility so that more complete technology data can be obtained in flight testing. Discussions are now in progress with the Navy to plan the details of NASA's participation and the reimbursement by the Navy for the NASA activity.

While energy efficiency for subsonic civil aviation is given our highest priority concentration in the proposed FY 1978 NASA Aeronautics program, NASA is already involved in assessing its other programs, needs, and opportunities in preparation for the planning cycle for FY 1979. Meanwhile, NASA is confident that its FY 1978 budget request provides for a balanced program which effectively addresses the technology problems of today and maintains a necessary core of research preparation for the future.

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY AERONAUTICS FY 1978 BUDGET REQUEST

FY 1977	FY 1978
\$190.1 M	\$231.0 M

22% INCREASE IN AERONAUTICS PROGRAM

Figure 1

FY 1978 HIGHLIGHT AREAS

- **AIRCRAFT ENERGY EFFICIENCY/CONVENTIONAL TAKEOFF & LANDING (ACEE / CTOL)**
- **SUPERSONIC CRUISE AIRCRAFT RESEARCH (SCAR)**
- **HELICOPTERS/VERTICAL TAKEOFF AND LANDING (VTOL)**
- **GENERAL AVIATION**
- **SHORT-HAUL/SHORT TAKEOFF AND LANDING (STOL)**
- **GENERIC TECHNOLOGY**
- **RESEARCH AND TECHNOLOGY (R&T) BASE**

HELICOPTERS / VTOL

ARMY / NASA ROTOR SYSTEMS RESEARCH AIRCRAFT (RSRA)



Figure 3

HELICOPTERS / VTOL

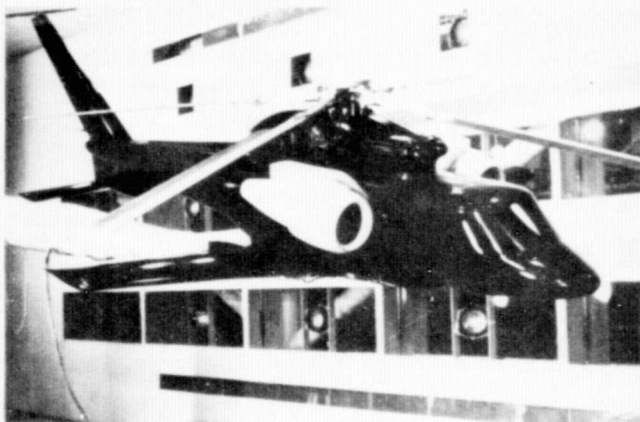
ARMY / NASA TILT ROTOR RESEARCH AIRCRAFT (TRRA)



HELICOPTERS / VTOL

ADVANCED ROTOR RESEARCH

WIND-TUNNEL



FLIGHT

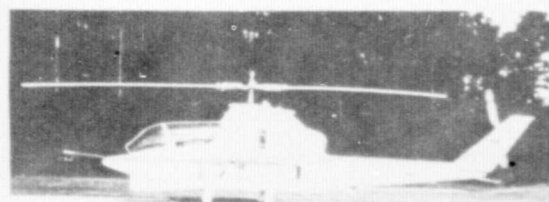
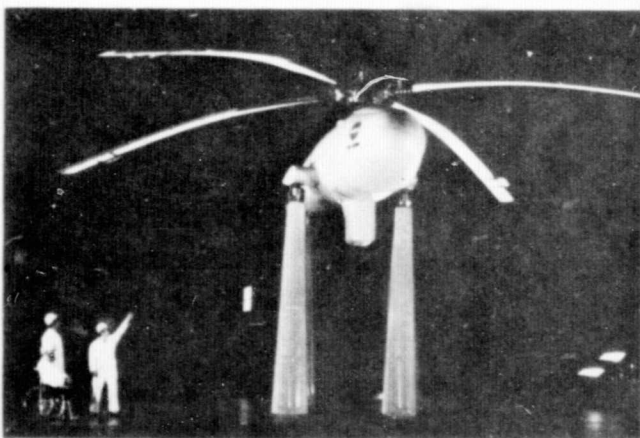
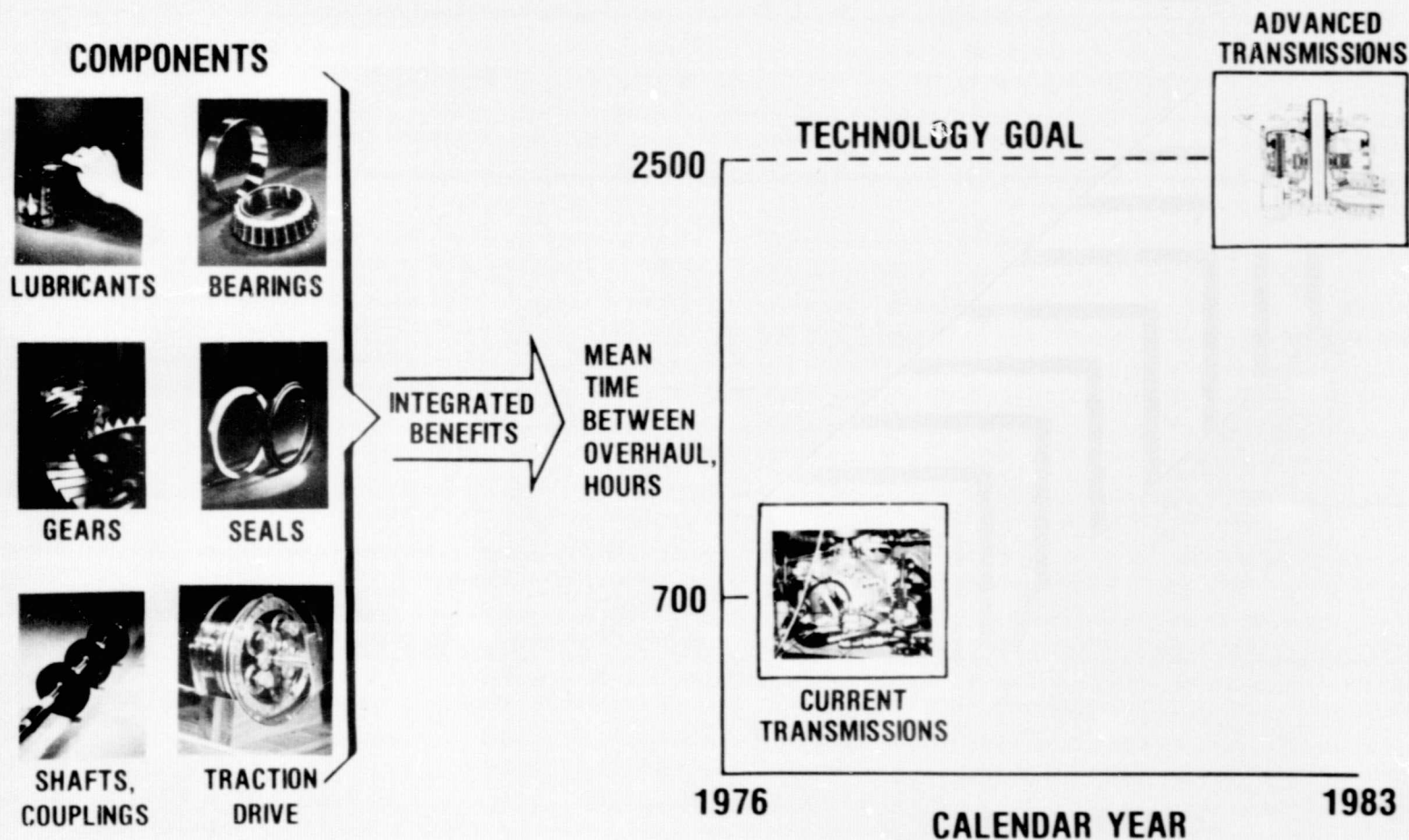


Figure 5

NASA HQ RA77-1176 (3)
12-29-76

HELICOPTERS/VTOL

ADVANCED HELICOPTER TRANSMISSION TECHNOLOGY



NASA HQ-RX-77-1613 (3)
1-26-77

Figure 6

HELICOPTERS / VTOL

HEAVY LIFT AIRSHIP



Figure 7

NASA HQ RX77-1157 (3)
12-28-76

GENERAL AVIATION

GAW-1 WING ON BEECH 77 PROTOTYPE



Figure 8

GENERAL AVIATION

GENERAL AVIATION TECHNOLOGY

AIRFOIL DEVELOPMENT

SUPER CRITICAL



$M \geq 0.7$

MEDIUM SPEED

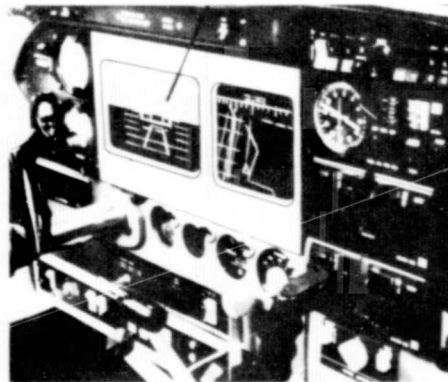


$M = 0.3-0.5$

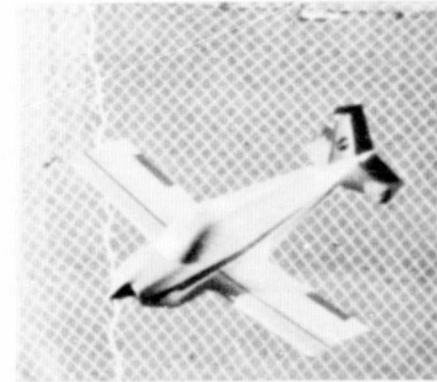
LOW SPEED (GAW)



$M \leq 0.2$

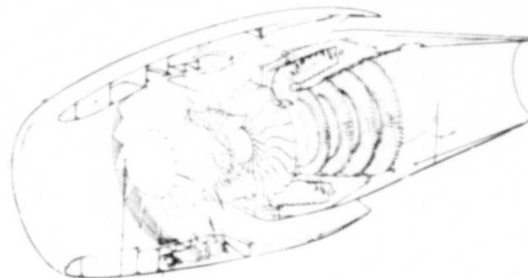


LOW-COST AVIONICS

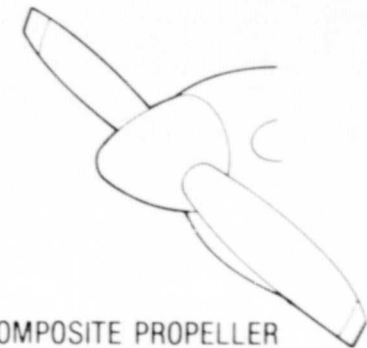


STALL/SPIN RESEARCH

PROPULSION TECHNOLOGY



QCGAT



COMPOSITE PROPELLER

25

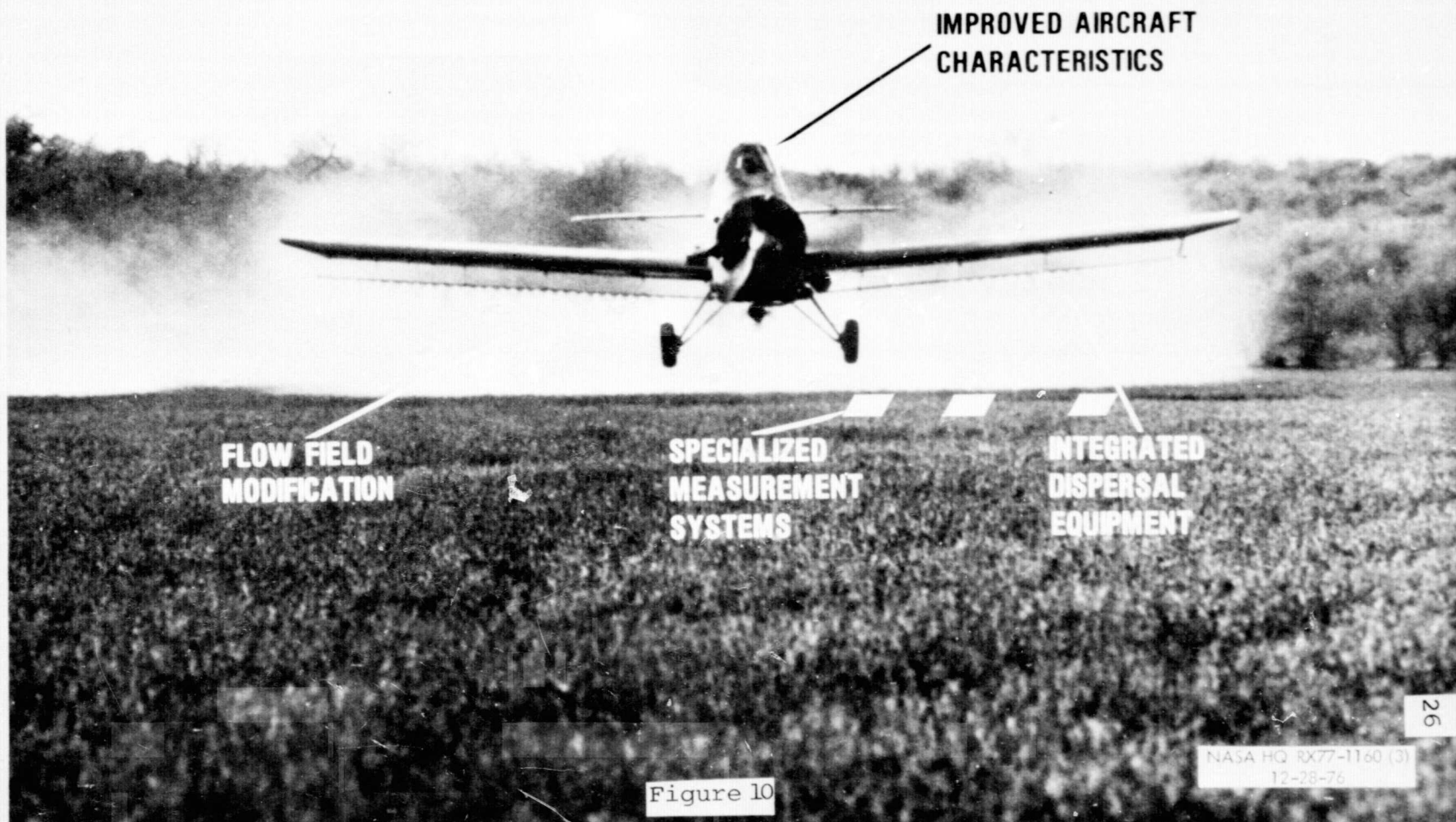
NASA HQ 8X77-1159 (3)
12-28-76

Figure 9

GENERAL AVIATION

AERIAL APPLICATIONS TECHNOLOGY

TECHNOLOGY OBJECTIVES



SHORT-HAUL / STOL

QUIET SHORT-HAUL RESEARCH AIRCRAFT (QSRA)

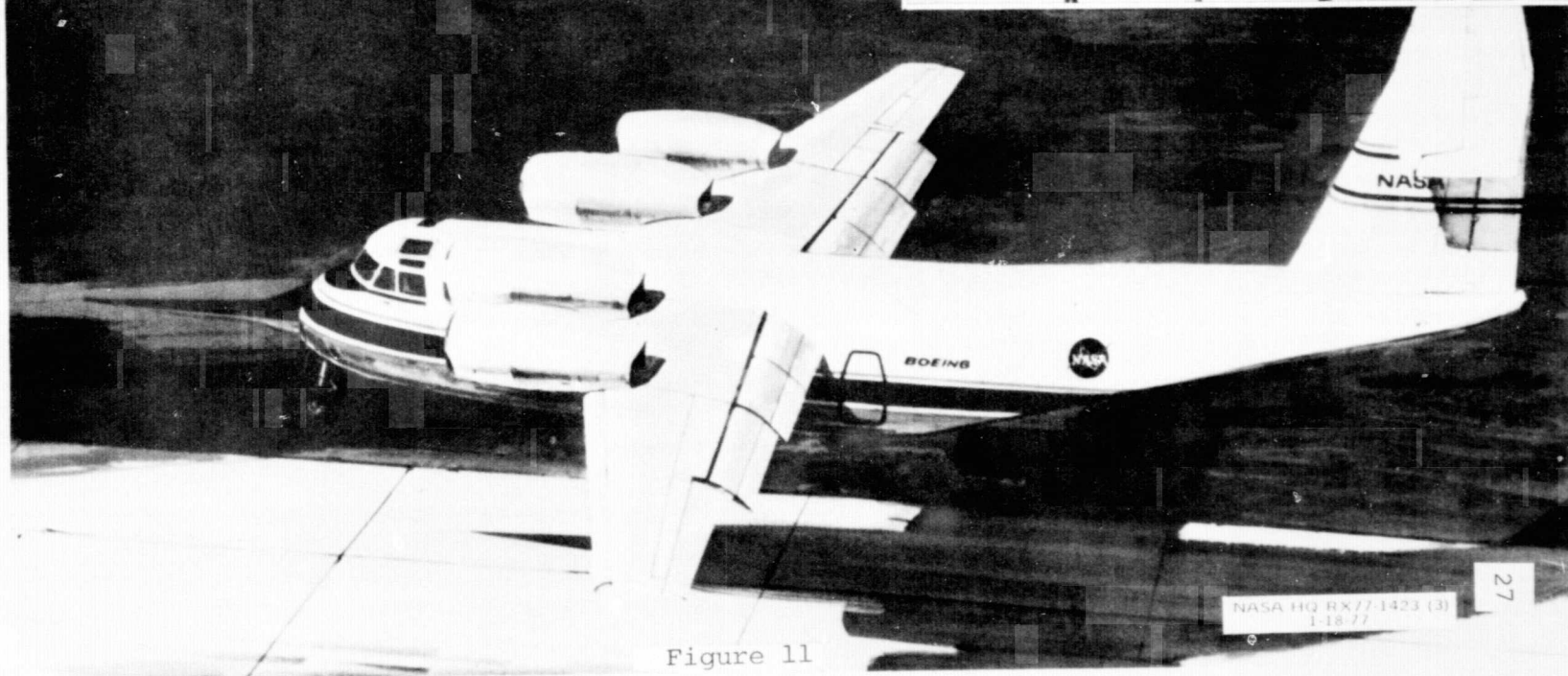
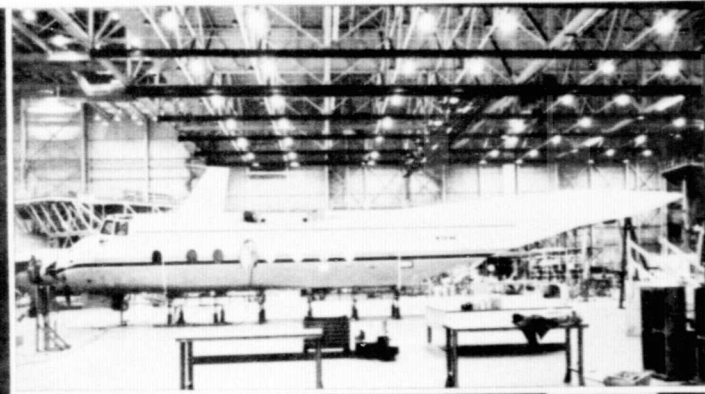
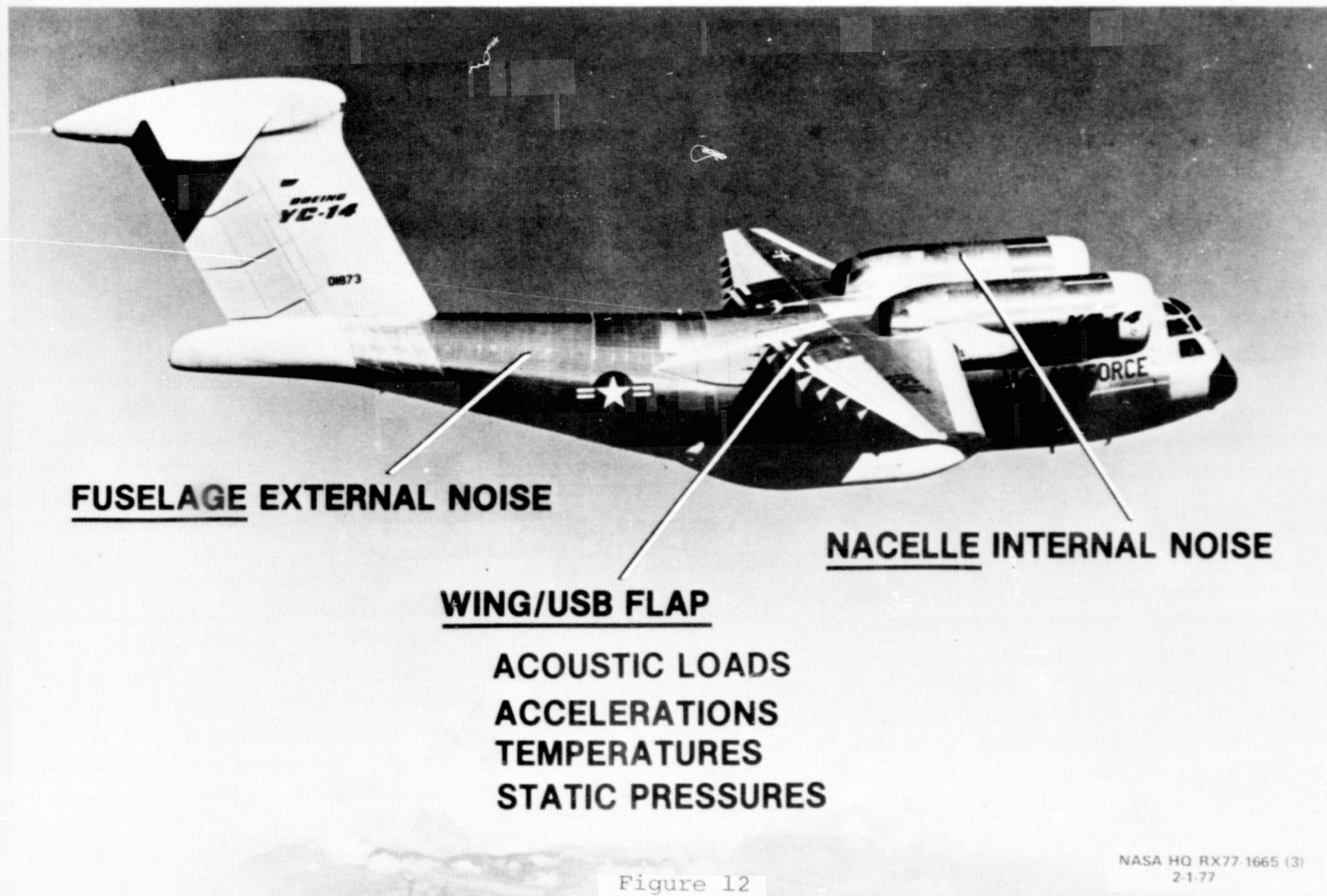


Figure 11

NASA HQ RX77-1423 (3)
1-18-77

SHORT HAUL/STOL

NASA FLIGHT RESEARCH IN USAF AMST DEVELOPMENT PROGRAM



SHORT-HAUL / STOL

QUIET CLEAN SHORT-HAUL EXPERIMENTAL ENGINE - ON TEST AT GE

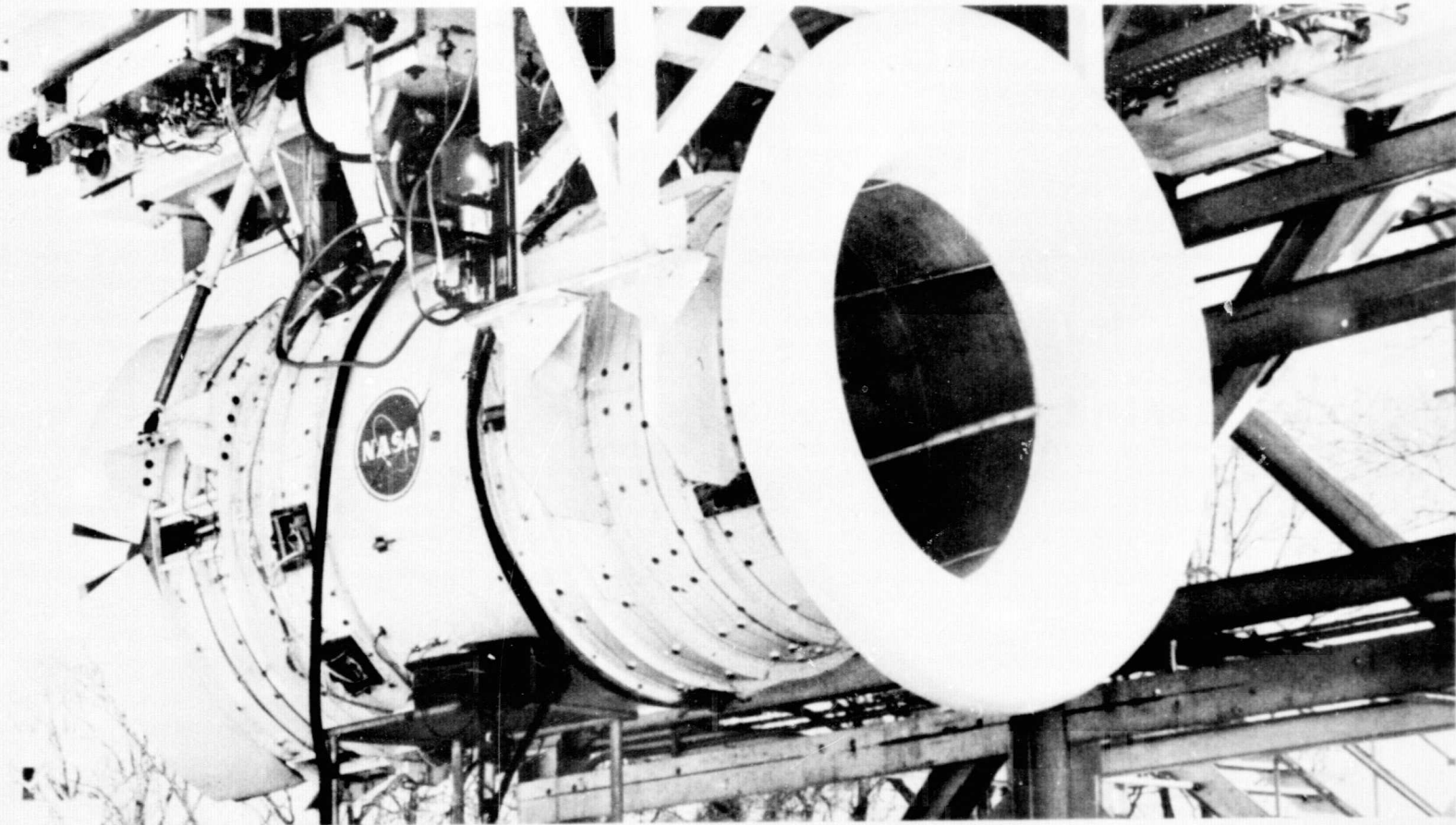


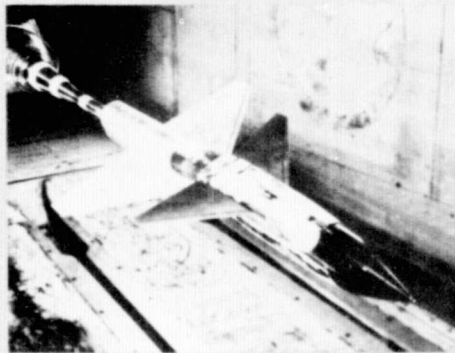
Figure 13

NASA HQ RL77-1215 (3)
1-3-77

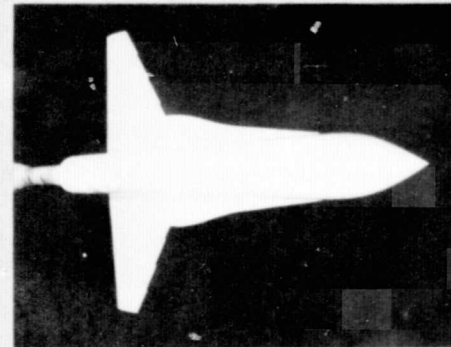
GENERIC TECHNOLOGY

CONFIGURATION RESEARCH LEADS TO COMBAT AIRCRAFT SUPERIORITY

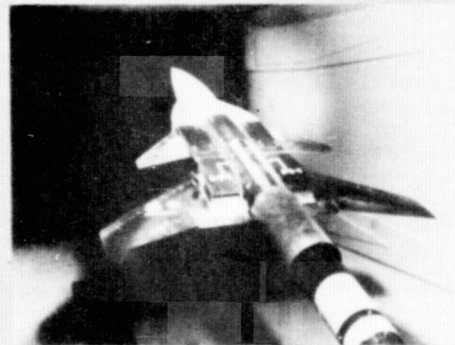
EMERGING RESEARCH CONCEPTS



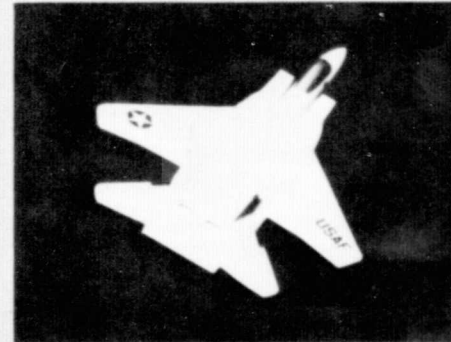
CANARDS



STRAKES



BLOWING AND VECTORING



F-15 WITH 2-D

NASA HQ RQ77-1136(2)
12-27-76

Figure 14

GENERIC TECHNOLOGY

**CONFIGURATION RESEARCH LEADS
TO COMBAT AIRCRAFT SUPERIORITY**

PROOF-OF-CONCEPT TESTING

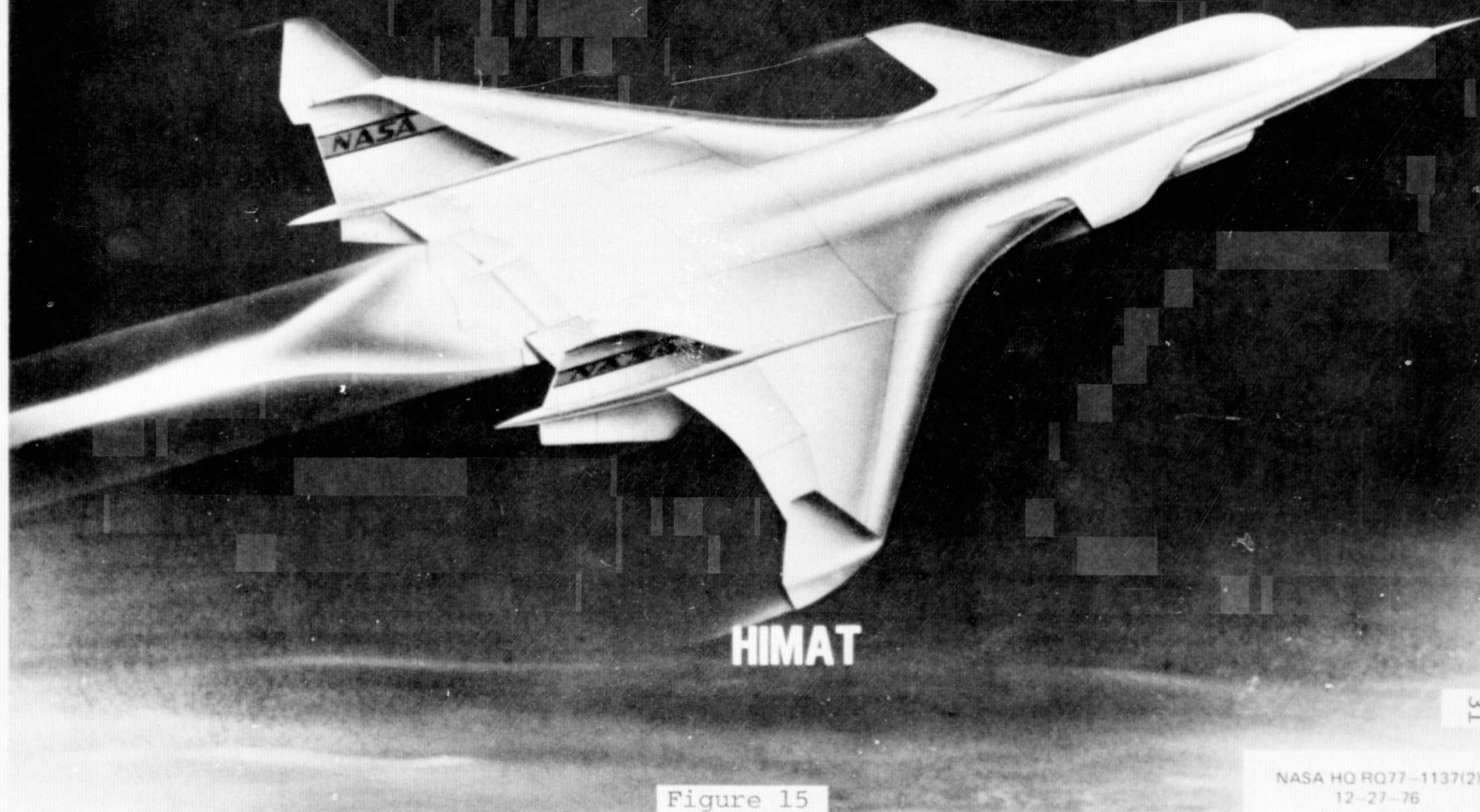


Figure 15

NASA HQ RQ77-1137(2)
12-27-76

GENERIC TECHNOLOGY

AERONAUTICAL OPERATING SYSTEMS TECHNOLOGY

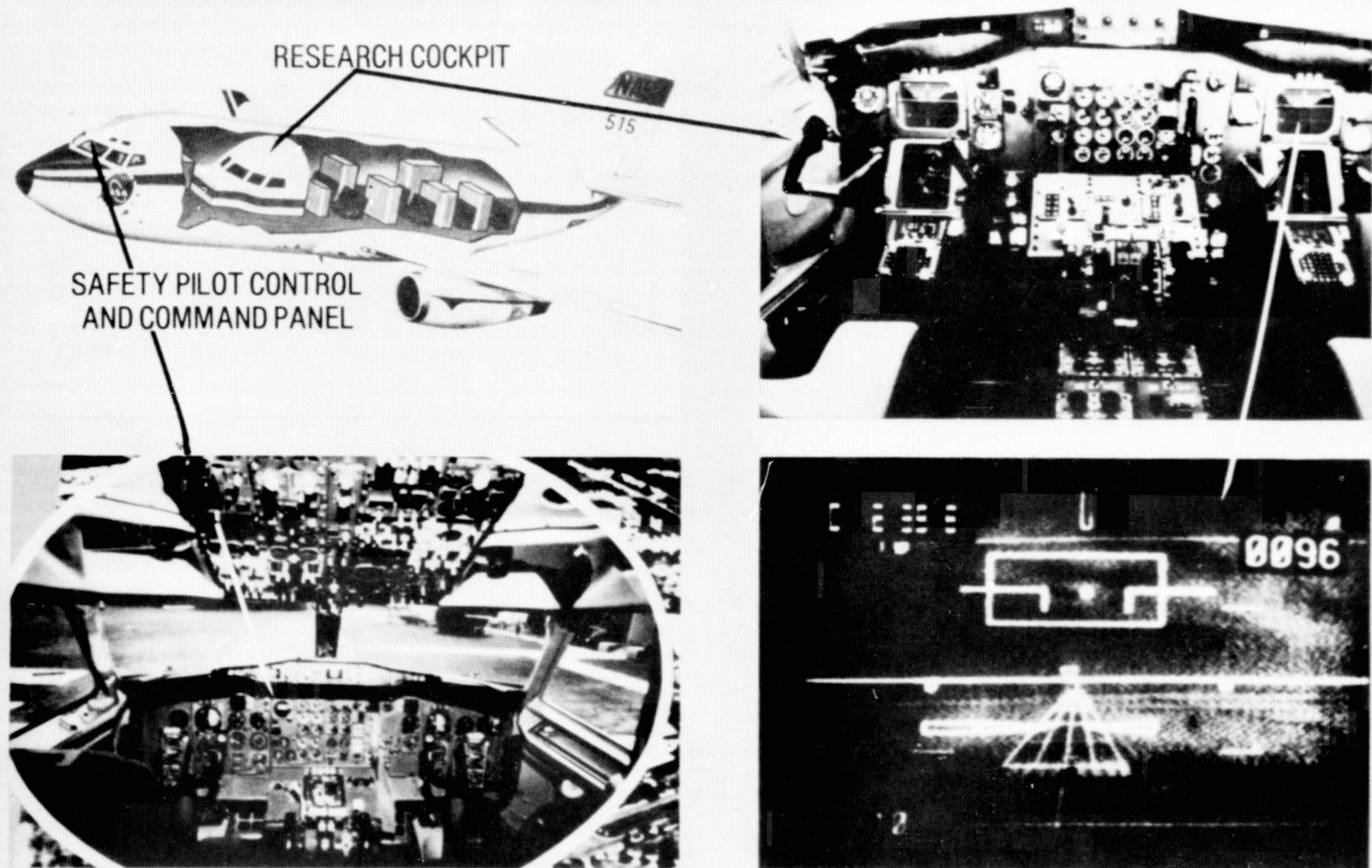
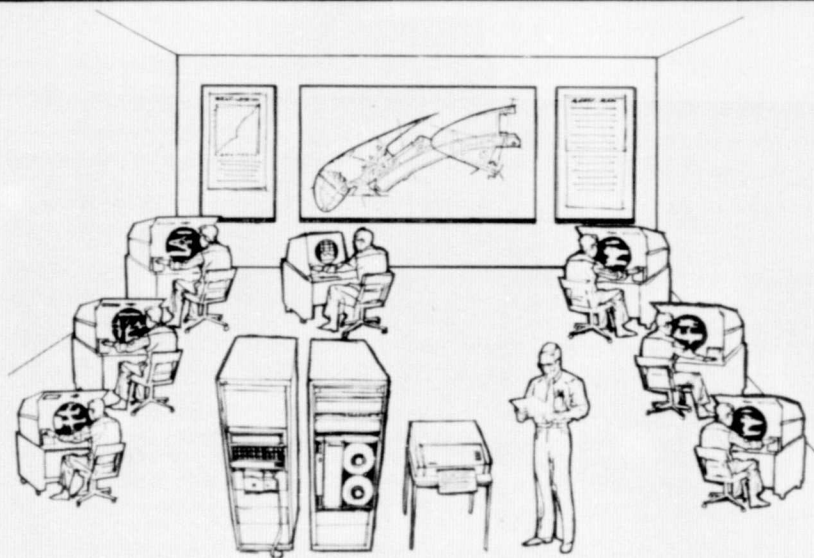


Figure 16

NASA HQ RX77-1589 (3)
1-27-77

GENERIC TECHNOLOGY

IPAD INTEGRATED PROGRAMS FOR AEROSPACE VEHICLE DESIGN



IPAD YIELDS

- 25% REDUCTION IN DESIGN COST
- 50% REDUCTION IN DESIGN TIME

FY 1978 HIGHLIGHT - FIRST RELEASE TO INDUSTRY

NASA HQ RW77-1214 (3)
1-3-77

Figure 17

GENERIC TECHNOLOGY

TECHNOLOGY IMPACT ON AIRCRAFT POLLUTION LEVELS (NO_x AT CRUISE CONDITIONS)

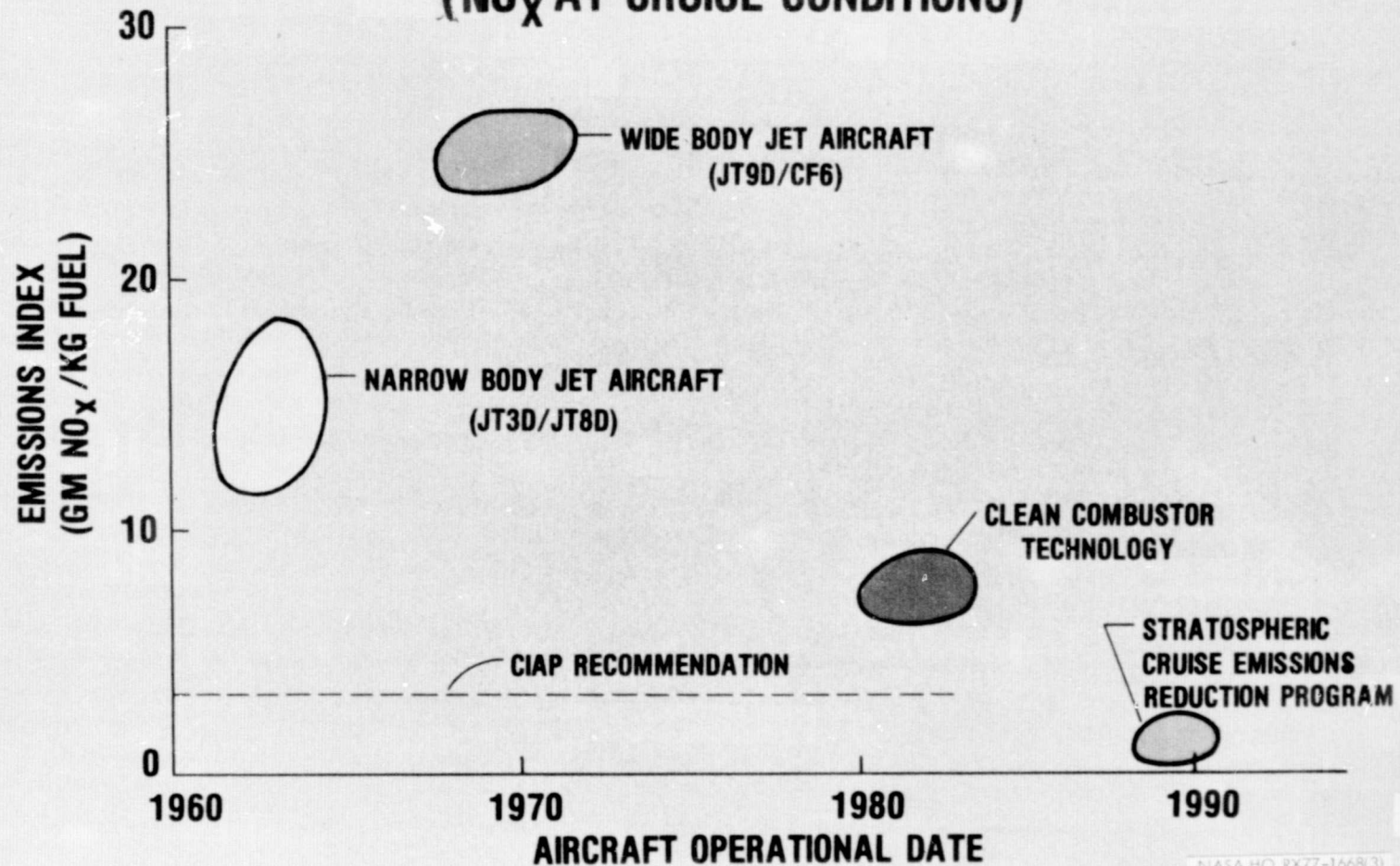


Figure 18

R&T BASE

THERMAL BARRIER COATING FOR TURBINE BLADES

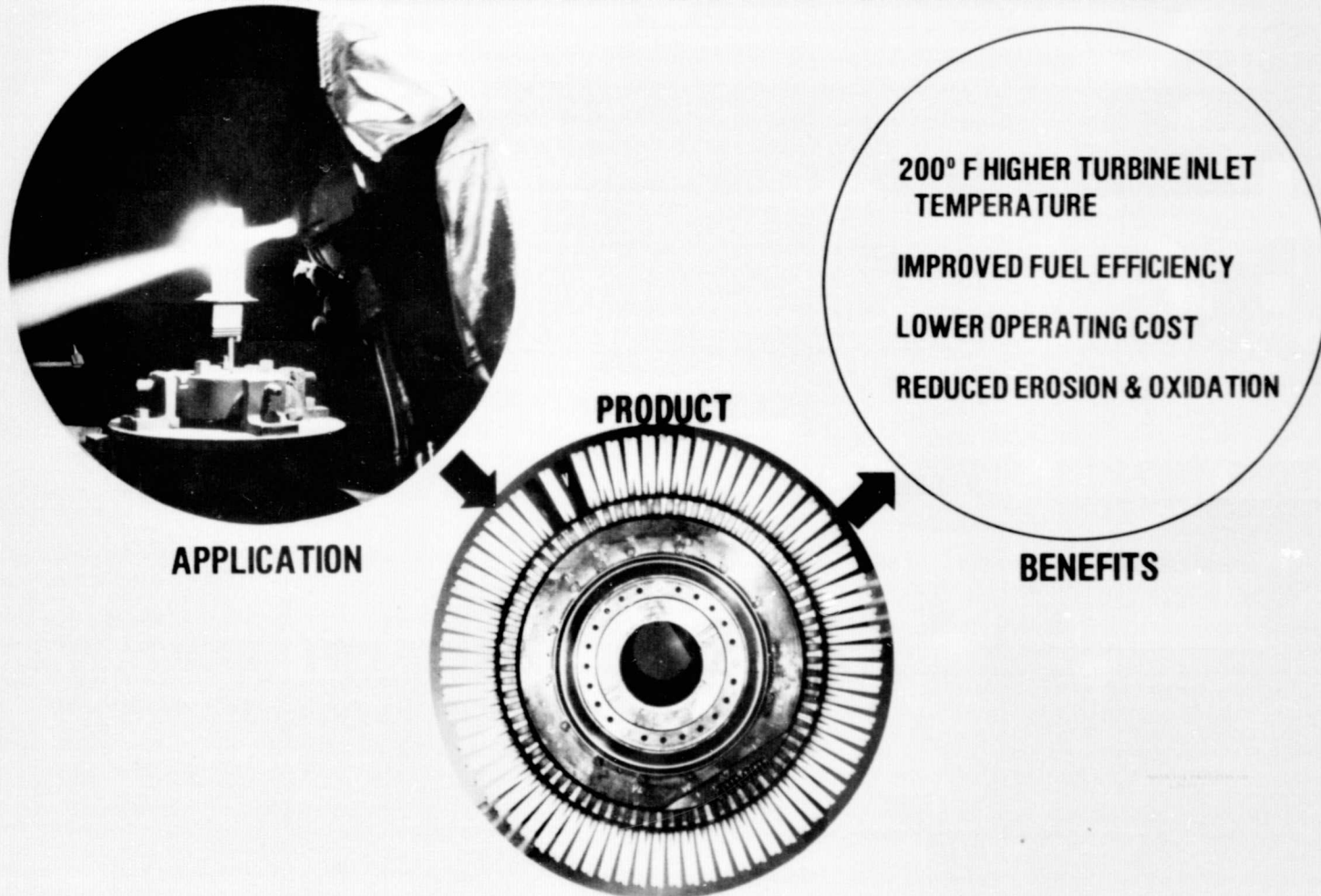
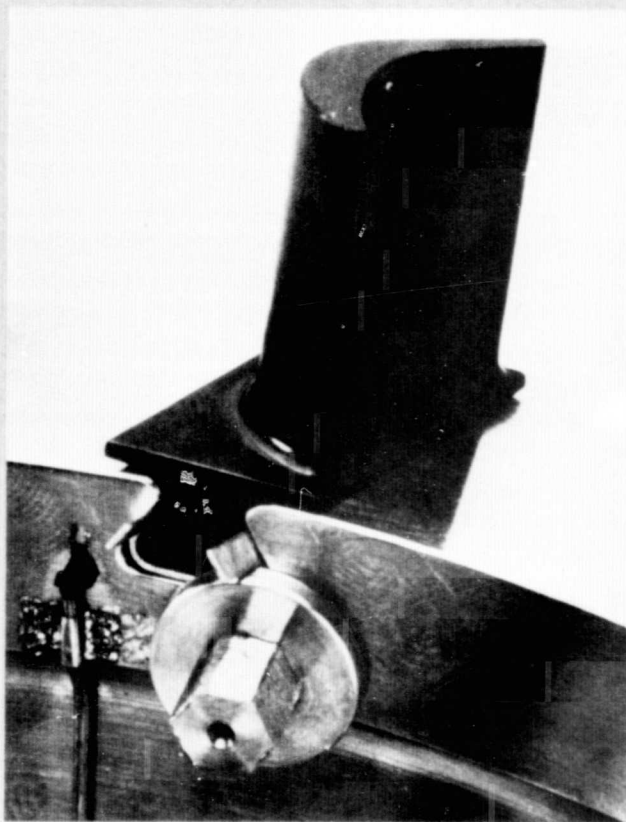


Figure 19

R&T BASE

CERAMIC TURBINE BLADES



OBJECTIVES

- CUT TOTAL BLADE COST BY 25%
- SUPERIOR CORROSION RESISTANCE
- USE OF NON-STRATEGIC MATERIALS

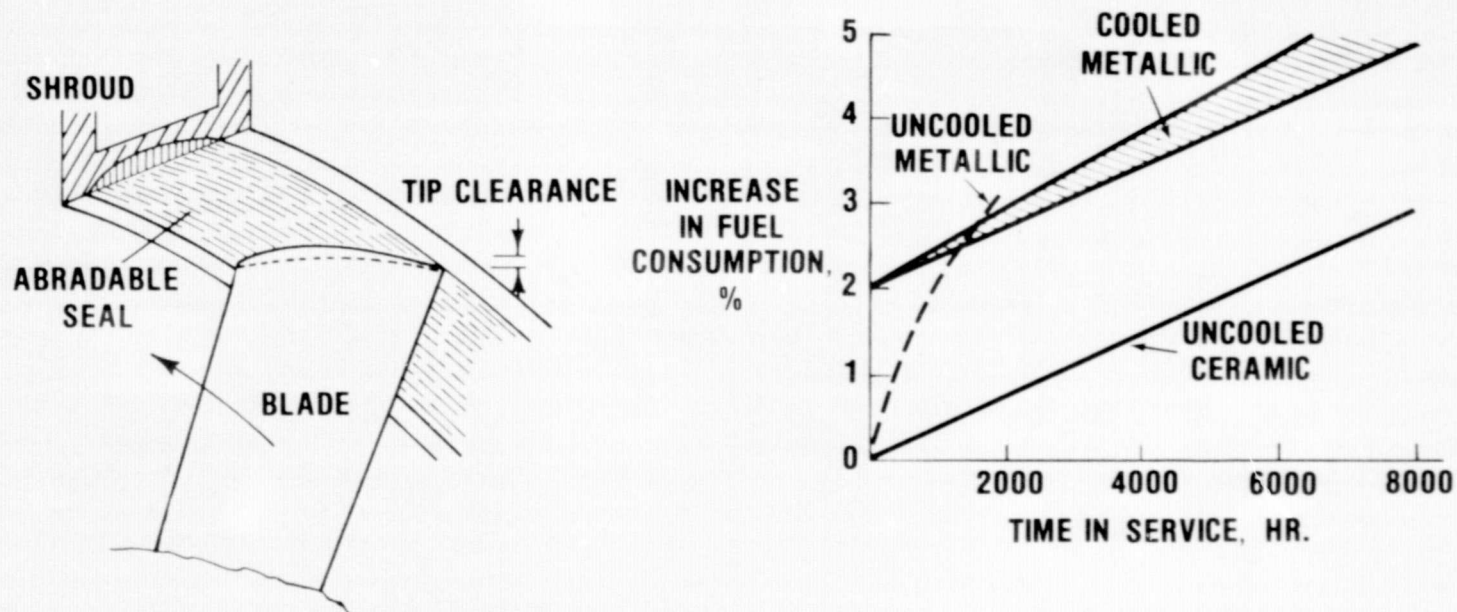
FY 1978 PLAN

- 500 HRS. TEST AT 2200° F

Figure 20

R&T BASE

ABRADABLE CERAMIC SEALS



$\frac{1}{100}$ INCH INCREASE IN TIP
CLEARANCE MEANS 1% LOSS
IN TURBINE PERFORMANCE

Figure 21

R&T BASE

FIRE RESISTANT AIRCRAFT INTERIORS

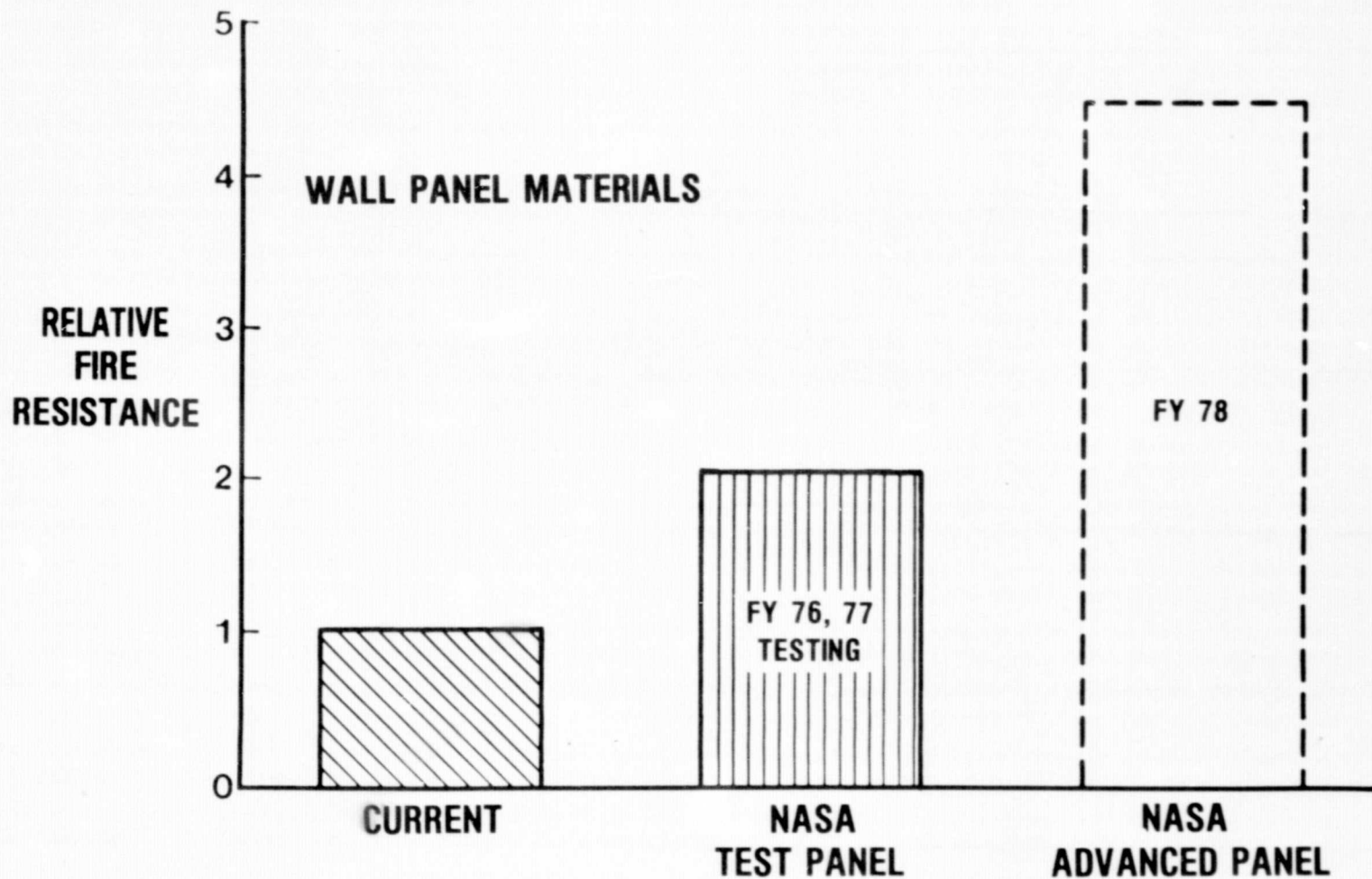


Figure 22

R&T BASE

FLIGHT TESTS TO CONFIRM FLUTTER PREDICTION

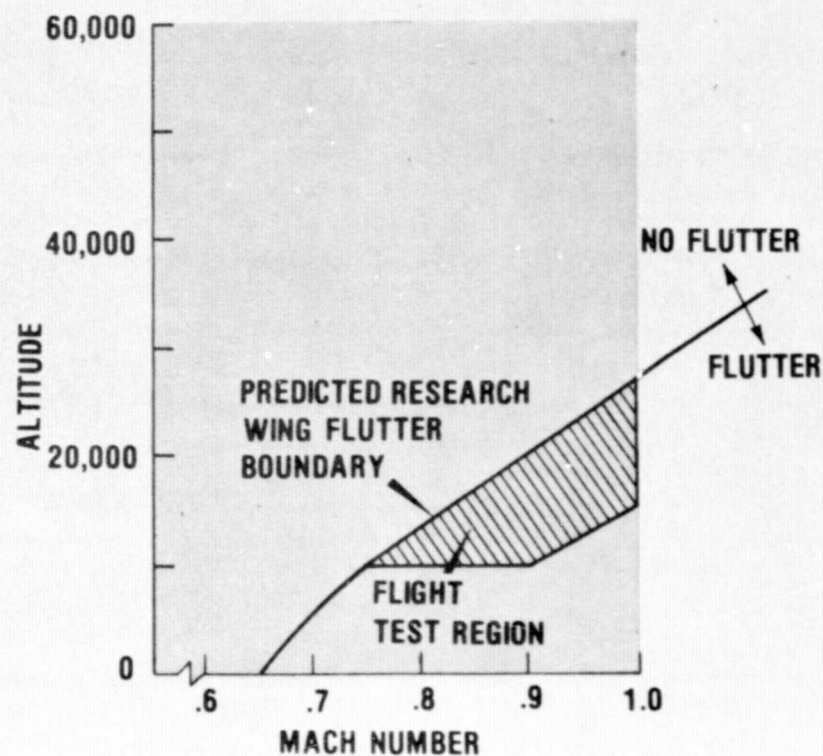
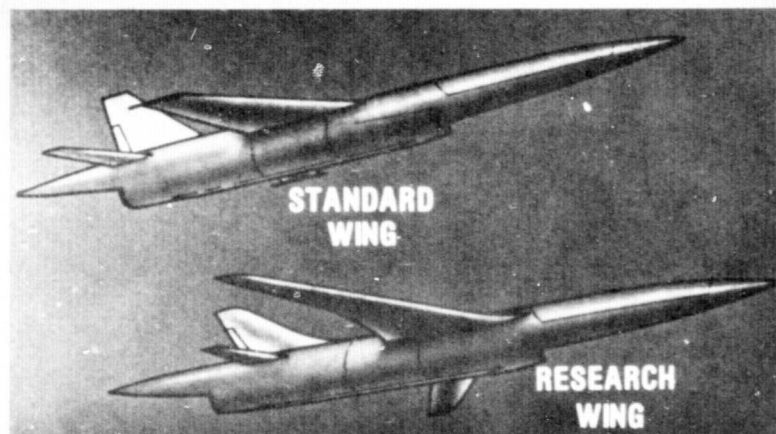
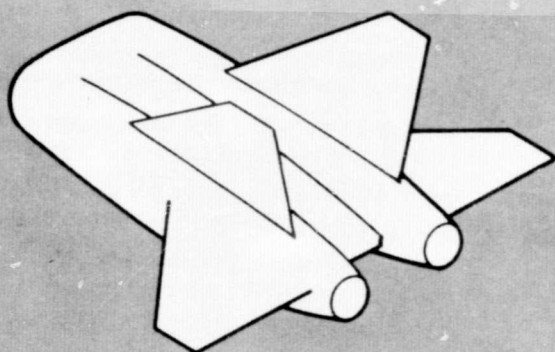


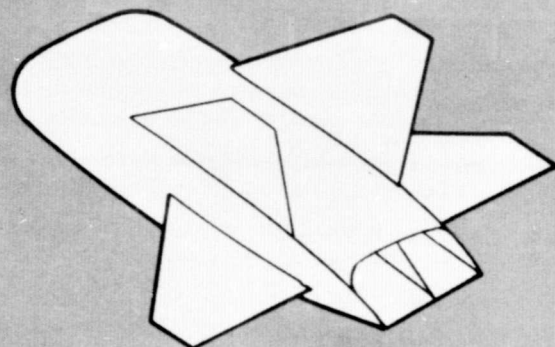
Figure 23

R&T BASE

PROPULSION SYSTEM INSTALLATION RESEARCH



AXISYMMETRIC NOZZLE (CURRENT)



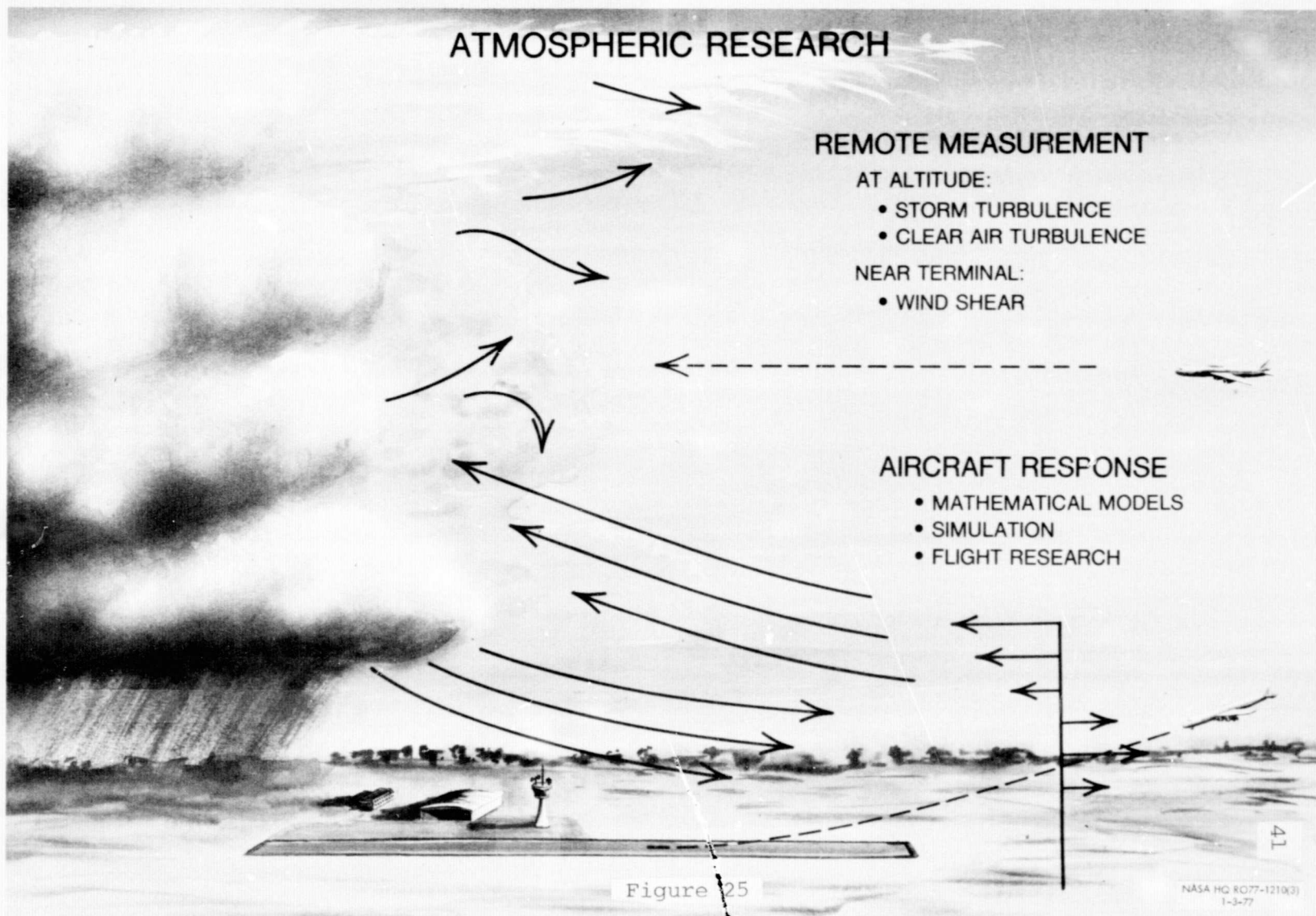
**NON-AXISYMMETRIC NOZZLE (2-D)
(FUTURE)**

OBJECTIVES:

- **REDUCED AIRCRAFT DRAG**
- **THRUST VECTORING FOR
MANEUVERABILITY AND SAFETY**
- **SIMPLER MECHANISMS**
- **REDUCED WEIGHT**
- **LOWER COST**
- **LONGER NOZZLE LIFE**

Figure 24

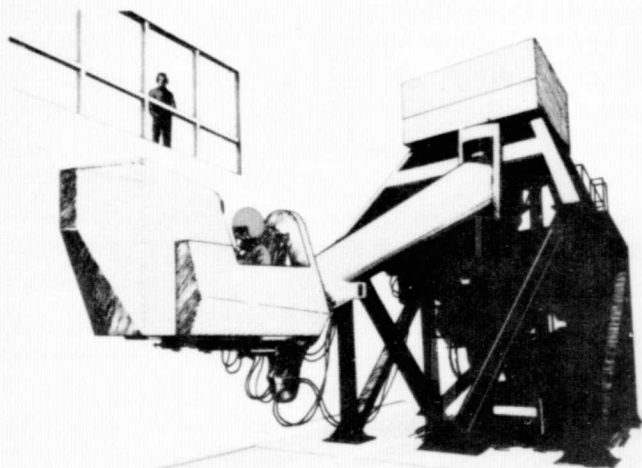
R&T BASE



R & T BASE

INCREASE LANDING SAFETY AND ECONOMY

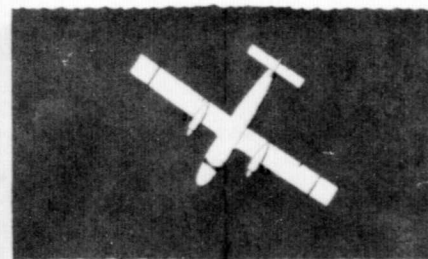
MOVING-BASE SIMULATOR



EXPLORE DIRECTIONAL CONTROL
AND BRAKING PROBLEMS

CROSSWIND LANDING GEAR FLIGHT TESTS

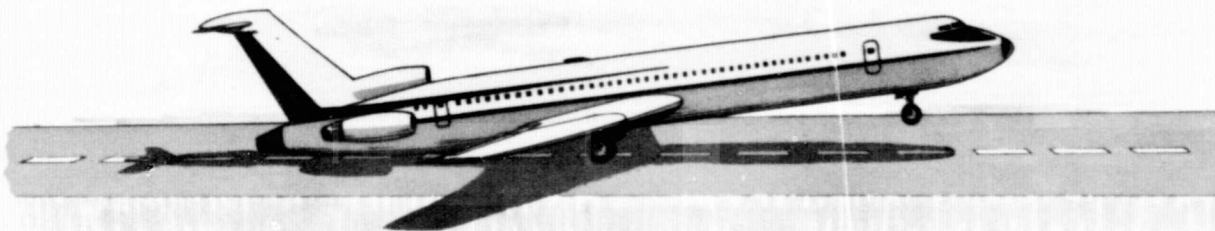
WIND →



INVESTIGATE

- PILOTING TECHNIQUES
- MODES OF OPERATION
- OPERATIONAL LIMITS

AIR CARRIER EVALUATION

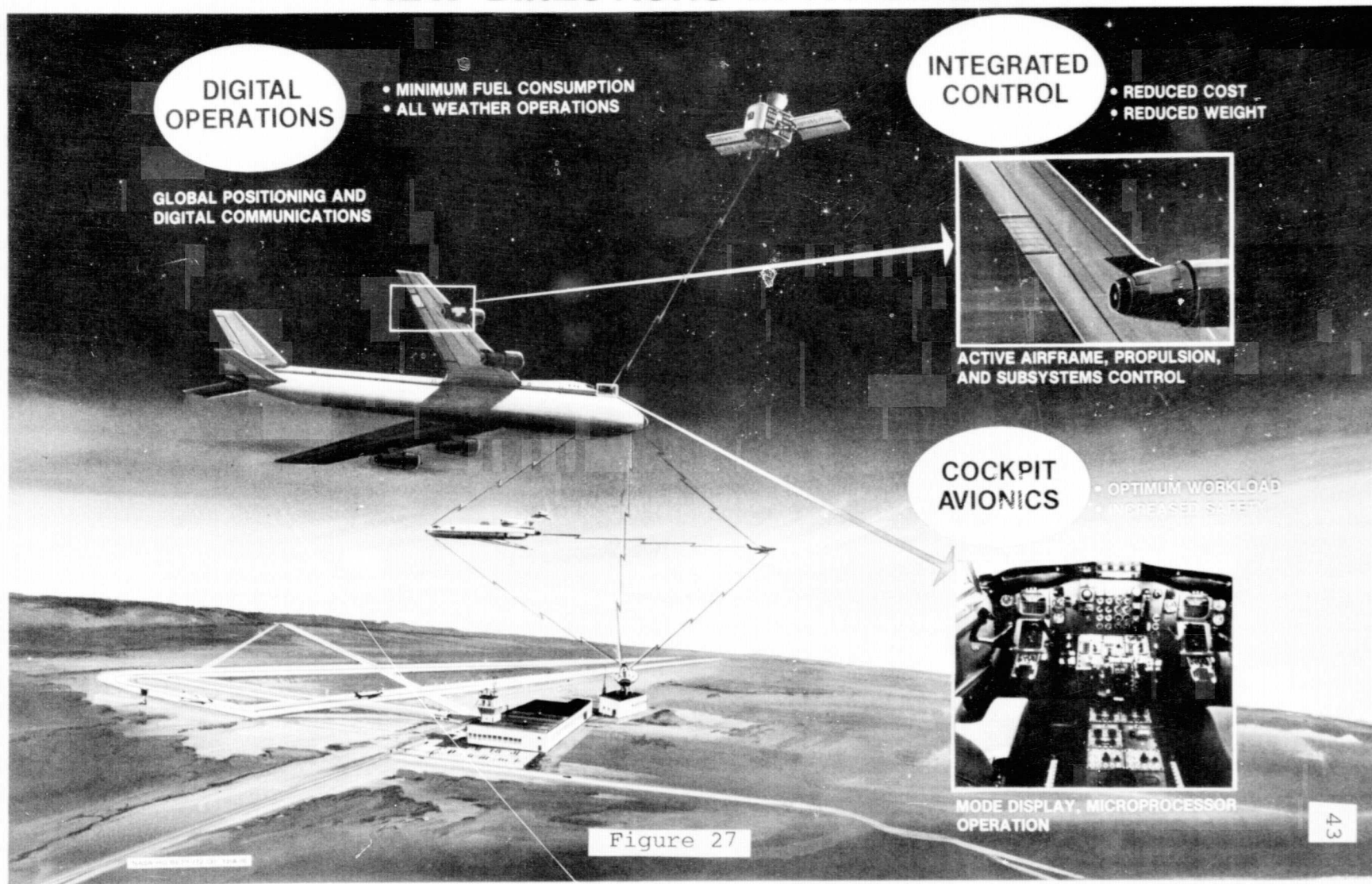


NEW TIRE MATERIALS FOR IMPROVED WEAR AND SAFETY

Figure 26

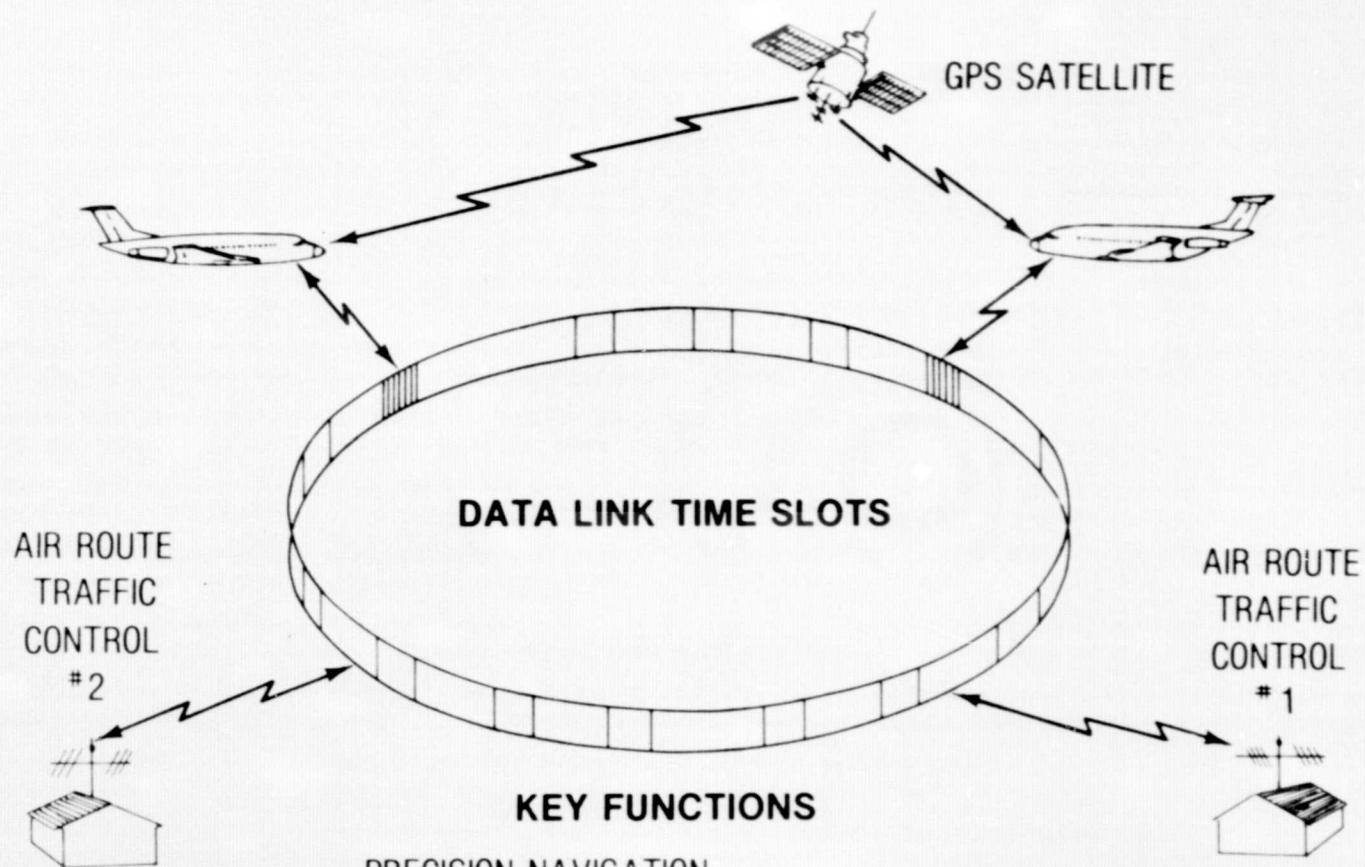
R & T BASE

NEW DIRECTIONS IN AVIONICS



R&T BASE

DIGITAL OPERATIONS



KEY FUNCTIONS

PRECISION NAVIGATION
COLLISION ASSESSMENT
AUTOMATED WEATHER & ROUTE DATA
AUTOMATED POSITION & VELOCITY DATA

Figure 28

R&T BASE

INTEGRATED CONTROLS

**REDUCED A/C WEIGHT
INCREASED A/C EFFICIENCY**

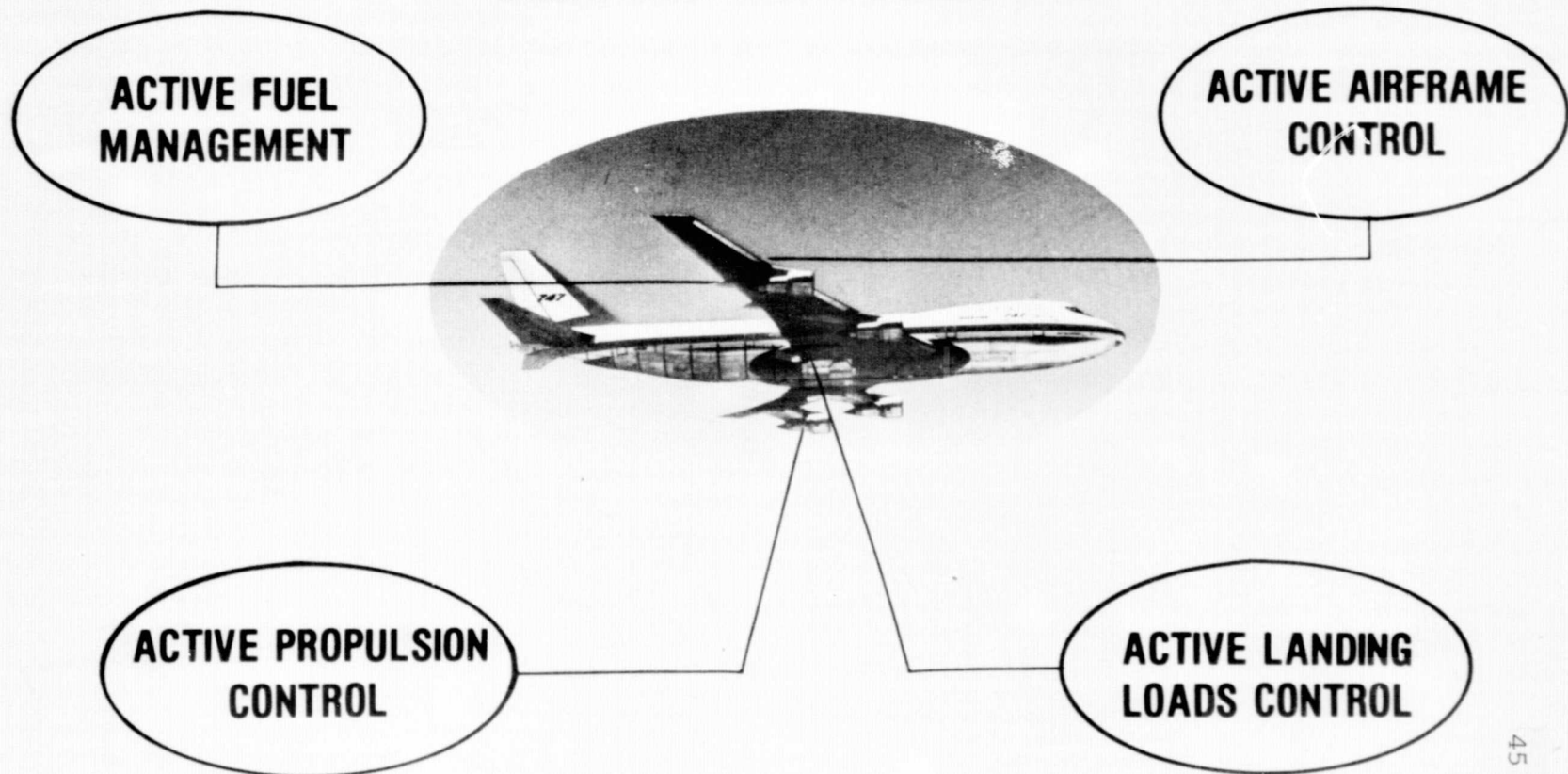
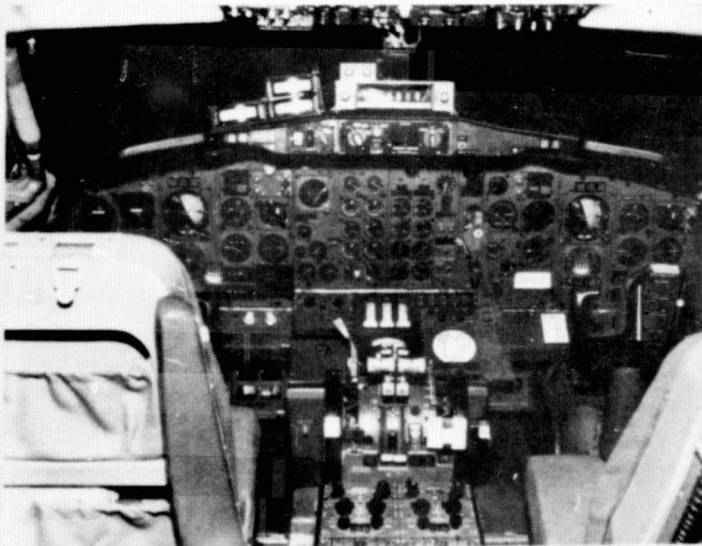


Figure 29

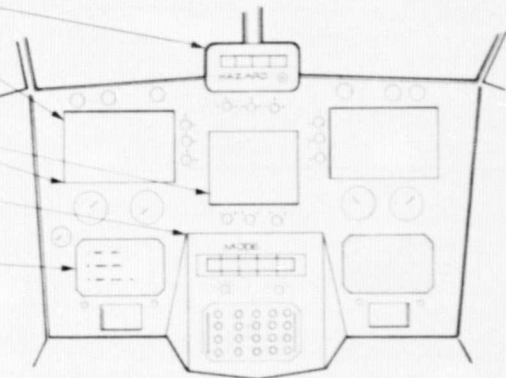
R&T BASE

COCKPIT AVIONICS



CURRENT TECHNOLOGY

- HAZARD WARNING/PRED. SYSTEM IMPLEMENTATION
- ADVANCED DISPLAY DEVICES
- REDUNDANT DISPLAY MANAGEMENT
- AUTOMATED PROCEDURES IMPLEMENTATION
- IMPROVED INFORMATION DISPLAY TECHNIQUES



ADVANCED TECHNOLOGY INTERGRATED COCKPIT

Figure 30

SECTION I-C. AIRCRAFT ENERGY EFFICIENCY TECHNOLOGY

In FY 1976, NASA initiated a major new technology effort, the Aircraft Energy Efficiency (ACEE) Program, to provide the basis for the design of derivative and new transport aircraft that are significantly more energy efficient than today's transports.

The elements of the Aircraft Energy Efficiency Program are shown in Figure 1. Currently the program consists of five focused technology efforts in Engine Component Improvement, Energy Efficient Engine, Energy Efficient Transport, Laminar Flow Control, and Composites. A major expansion of the ACEE Program is proposed for FY 1978 with the addition of a new propulsion program in turboprops and the start of the second phases of the Energy Efficient Engine and Energy Efficient Transport.

The three ongoing programs which are proceeding as planned and for which no expansion is required in FY 1978 are the Engine Component Improvement, Laminar Flow Control, and Composite Programs. Briefly, in the Engine Component Improvement effort NASA is working with the engine manufacturers and the airlines to identify sources of in-service performance deterioration and to develop improved engine components which will reduce fuel consumption in current engines. The Laminar Flow Control Program is aimed at greatly reducing the drag of future aircraft by maintaining smooth, or laminar, flow over the surface. Work is continuing on systems definition and concept evaluation to assess alternative designs which are technically feasible and economically attractive for a laminar flow aircraft of the 1990's. Through the Composite Primary Aircraft Structures Program, activity is under way in an attempt to accelerate the use of composite materials in commercial aircraft. Work is continuing on the design, development, certification, and flight service of a diverse mix of secondary structures and medium- and large-sized primary structures to give the industry experience and confidence in the use of composite materials to reduce the weight of new aircraft.

The following describes in more detail the programs where new initiatives are proposed for FY 1978. The programs will be discussed in the order shown in Figure 2, starting with Advanced Turboprops.

Turboprops-Phase I: Modern high-speed turboprops have the potential of saving significant amounts of fuel, on the order of 20 to 30 percent over modern high-bypass turbofan engines. The goal of this new propulsion program is to develop the technology to demonstrate that future airplanes powered by advanced turboprops will be comfortable, quiet, safe and economical to operate. Figure 3 shows what an advanced turboprop powered aircraft of the future might look like and lists the four phases of the Advanced Turboprop Program. Phase I calls for the extensive development of propeller aerodynamics and noise technology. Other phases shown in the figure, which are planned for FY 1980 and beyond, call for future decisions based on the success of the Phase I program.

Recent wind tunnel tests conducted in the R&T Base program have demonstrated that advanced multibladed propellers can achieve the same high efficiency levels as older propellers while operating at a much higher cruise speed and altitude. In FY 1978, wind-tunnel tests to evaluate propeller aerodynamics will continue (Figure 4). In addition, propeller systems will be designed, fabricated, and tested to study the tradeoff between propeller efficiency, noise and structural limits.

A major technology area to be addressed in Phase I is propeller acoustics. Wind-tunnel tests to measure and document the noise levels associated with modern high-tip-speed propellers will be conducted in FY 1978 and analytical models will be perfected to improve noise prediction and propeller design capabilities. Propeller source noise will be addressed through advanced design techniques, such as blade sweep, to reduce community noise. At a cruise Mach number of 0.8, and with the high power loading required, the blade tips in the advanced design propeller rotate at supersonic speeds causing a

potential noise problem. Blade sweep has been used in the model shown in the figure to weaken the shock wave at the tip, but noise is still likely to be a problem and other noise attenuation methods will be investigated, such as reducing the blade thickness, increasing the number of blades, or using dual counter-rotating propellers. Effective lightweight acoustic treatment of the cabin walls will also be investigated in order to preserve passenger comfort and avoid a severe installation weight penalty.

In addition to being a potentially efficient source of propulsion for commercial applications, advanced turbo-props may have military applications as well. The Navy has expressed interest in the program in terms of its possible utility to a future long-endurance land-based sea patrol aircraft.

Energy Efficient Engine-Phase II: The objective of the Energy Efficient Engine Program is to develop and demonstrate the technology base for achieving higher thermodynamic and propulsive efficiencies in future turbofan engines. The goal is to reduce specific fuel consumption by 10 to 15 percent over current high-bypass-ratio engines while simultaneously reducing direct operating costs, emissions, and noise levels. The program is divided into two phases as shown in Figure 5.

Phase I contracts have been awarded to the two manufacturers of large commercial engines, Pratt & Whitney Aircraft and General Electric, for the engine definition studies. In these studies, the contractors will select the optimum size, thrust, thermodynamic cycle, and basic configuration of a new experimental energy efficient engine. The engine designs that will emerge will reflect the thinking of the individual company with respect to the type and the levels of technology to explore. However, both manufacturers are predicting that the advanced engine will require higher cycle pressure ratios, higher turbine inlet temperatures and higher bypass ratios than current engines. In FY 1978, and as part of Phase II, fabrication will begin on the high-pressure compressor,

combustor, and high-pressure turbine core components and on the fan and low-pressure turbine low spool components along with the mixer and nacelle. In Phase II, extensive development of these components is followed by refinement and further evaluation in high-pressure core and core/low spool engine system tests.

In response to industry recommendations to accelerate the program, Phase II has been structured to include the key elements necessary to demonstrate sufficient technology readiness by 1982 to give the engine companies confidence to commit to the development of derivative and new engines which could be in service by the mid to late 1980's.

The next 3 figures expand on each of the Phase II activities in more detail. First, to achieve the Energy Efficient Engine Program goals, major technology advances must be made in all the engine components shown schematically in Figure 6. The performance of the fan, compressor, combustor, and high- and low-pressure turbines will be evaluated experimentally in full-scale component tests to determine the performance characteristics in each of the areas listed on the bottom of the figure. The core components will then be assembled and tested as a core system for further refinement and modification (Figure 7). The core performance is critical in establishing a successful technology demonstration. It is in this rotating subsystem that the highest temperatures and pressures are encountered and where significant performance improvements can be made to reduce fuel consumption, using, for example, low aspect ratio blading in the compressor, active clearance control, ceramic coatings in the hot section, and advanced low-emission combustors.

Similarly, Figure 8 illustrates some of the advanced concepts that will be investigated for the low spool system, such as the use of a geared fan with composite blades, a mixed flow exhaust, and a high work factor, low-pressure turbine. After separate full-scale component tests, the fan, low-pressure compressor, low-pressure turbine, and exhaust nozzle will be assembled and matched with the core to evaluate performance in the complete engine system.

It is not NASA's intention to carry this engine through to prototype, development, or production programs. The engine system will be experimental in nature but flight-type in principle. All items contributing to fuel consumption, acoustics, and propulsion characteristics will be of flight design and construction as required to demonstrate the program goals.

Energy Efficient Transport-Phase II: The objective of the Energy Efficient Transport Program is to develop and demonstrate advanced aerodynamics and active controls technologies for early application to derivative and new transport aircraft. The program is divided into two phases as shown in Figure 9.

Phase I includes specific technology developments in aerodynamics and active controls leading to the definition of an advanced, integrated configuration. An important additional activity in Phase I is called Selected Concepts Development and is a joint NASA/industry effort to investigate those concepts which are of primary interest to the manufacturers in relation to their planned derivative or new aircraft. That activity leads directly into the evaluation of the most promising concepts in FY 1978 in Phase II. The other major thrust of the Phase II program is the development of an advanced flight control system. These activities are discussed below.

The Selected Concepts Evaluation activity can be divided into two parts: developments which have application to derivative aircraft, and technology which will apply primarily to new aircraft designs. Shown in the figure (Figure 10) are the three current wide-body transports--the 747, DC-10 and L1011. Also listed are the technologies that are being investigated and the activities to be performed in Phase II.

Under Wing Geometry Modifications, NASA and industry are investigating the addition of either winglets or wing-tip extensions to current wide-body transports to improve fuel efficiency. Before commitment to these wing modifications can be made, extensive wind-tunnel and flight tests are required to evaluate the aerodynamic and aeroelastic characteristics of the proposed configurations.

These wing geometry improvements will also mean higher aerodynamic loads which adversely affect structural design for strength, especially under maneuver load conditions. Active controls technology, particularly for gust alleviation, maneuver load control, and elastic mode suppression, will allow the incorporation of these wing modifications with the minimum corresponding structural changes. An important element of the Phase II activities is the design, construction and flight evaluation of a near-term active controls system for this purpose. The system will have nonflight-critical application, such that loss or disengagement of the system will not impact either the aircraft's mission or its safety.

Another opportunity for significant drag reduction is in improved propulsion system integration. Flow interactions among the large fan-jet nacelles, engine pylons and the wing lower surface can be improved through careful selection of relative positions, angles and shapes. This activity will lead to work on a long-duct nacelle and mixer and will involve extensive wind-tunnel tests, full-scale ground tests and flight experiments.

Figure 11 illustrates three possible new aircraft of the near future: the Douglas DCX-200, the Lockheed Reduced Energy RE1011, and the Boeing 7X7. The Selected Concepts Evaluation activity for these aircraft includes work on all-new wing designs with lower sweep and higher aspect ratio, using supercritical airfoil sections and compatible high-lift systems for takeoff and landing. The high-lift requirements for these new wing designs will be less demanding than for current transports, and there is promise that simpler, lower cost systems will be possible. This program will consist primarily of wind-tunnel tests, with some detailed analysis of structural and aerodynamic trades.

In active controls, one of the more likely applications to the next-generation transports will be for augmented longitudinal stability. This will permit an aircraft design with a reduced-size horizontal tail, with corresponding lower weight and trim drag. Significant fuel savings are possible with reduced static margins, and early incorporation of active controls for this nonflight-critical application is expected. The Phase II program will include the demonstration of this technology through

the flight test of a modified wide-body transport with a reduced-size horizontal tail and a stability augmentation system.

The last element under Selected Concepts Evaluation is the development of an advanced, flight-critical active controls system. Early work in this area, listed as Maximum Benefit Active Controls, is the preliminary configuration definition which will lead to a longer term effort on the full integration of advanced aerodynamics and active controls into the design of a new-generation, energy-efficient transport aircraft. The integration of technology developments in aerodynamics and active controls is indicated schematically in Figure 9, where the Phase I activities and the Selected Concepts Evaluation just described are combined with the design, hardware and software development, and demonstration of an advanced flight control system.

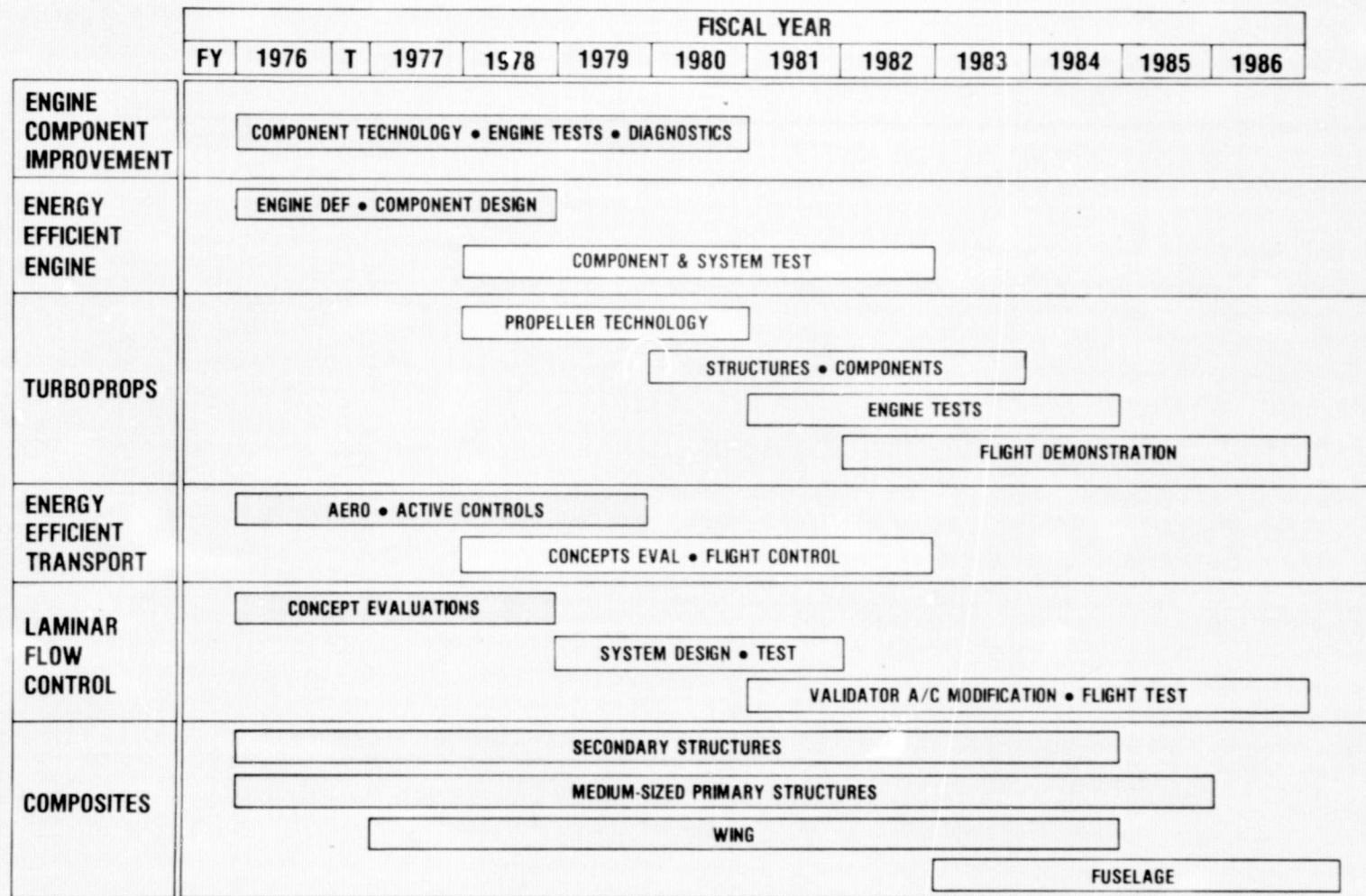
One of the most important requirements for the flight-critical application of active controls to commercial transports is the achievement of an extremely high level of reliability in all components of the system. The most important element of the advanced flight control system is the central computer, which must be fault-tolerant, i.e., capable of failure detection, identification and recovery. One such advanced computer system is illustrated in Figure 12. The central computer consists of software and an assortment of memory and processing units. In its initial configuration, blocks of these microprocessing units are assigned to the various tasks to perform flight control, navigation, flight management, and display functions. The computer continuously monitors and evaluates these functions on-line during a flight. If a failure or anomaly is detected, the fault-tolerant computer has the capability of identifying the memory or processing unit that is in error and of correcting the fault. Considered in the example is the case where a simultaneous failure occurs in the processing unit performing the navigation function and in one of the memory units assigned to flight control. The software logic detects the failure, identifies the malfunctioning units and reconfigures the computer by

reassigning the memory and processing units from the less critical display function so that the more important flight control and navigation functions continue undisturbed.

One of the major elements of the NASA program will be work on advanced computer systems such as the one just described. In FY 1978, laboratory breadboard hardware for the advanced computer system will be developed. This will lead to the evaluation of competitive approaches and the selection of the most promising computer system. Improved sensors and actuators will also be selected, leading to the preliminary design of an advanced flight control system. The system will be evaluated and optimized with the prime emphasis on system safety and cost effectiveness. These activities will then lead to a detailed flight control system design, hardware and software development, and demonstration to verify the control system performance and reliability.

The last figure (Figure 13) summarizes the Aircraft Energy Efficiency Program funding by element for FY 1978. As shown in the first column, the NASA budgeted amount for the ongoing programs totals \$53.8 million and the three new initiatives add an additional \$16.4 million. The total NASA funding for the ACEE program in FY 1978 is \$70.2 million given in the last column.

AIRCRAFT ENERGY EFFICIENCY PROGRAM



55

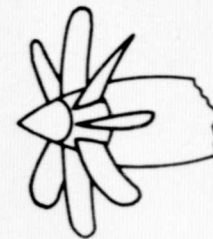
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2-77

Figure 1

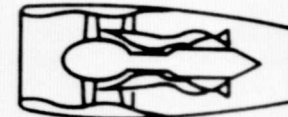
AIRCRAFT ENERGY EFFICIENCY PROGRAM

FY 1978 NEW EMPHASIS

ADVANCED TURBOPROP - PHASE I



ENERGY EFFICIENT ENGINE - PHASE II

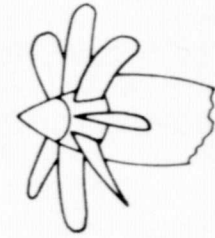


ENERGY EFFICIENT TRANSPORT - PHASE II



Figure 2

ADVANCED TURBOPROP PROGRAM



I-PROPELLER AERODYNAMICS/NOISE TECHNOLOGY

II-STRUCTURES/COMPONENT DESIGN/INTEGRATION

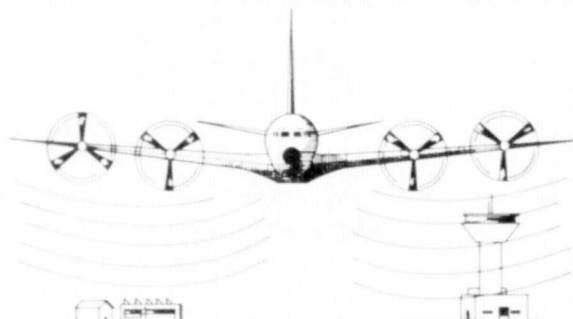
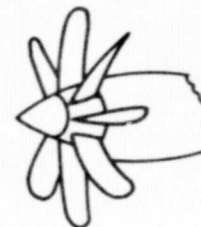
III-EXPERIMENTAL ENGINE

IV-TURBOPROP SYSTEM FLIGHT TEST

Figure 3

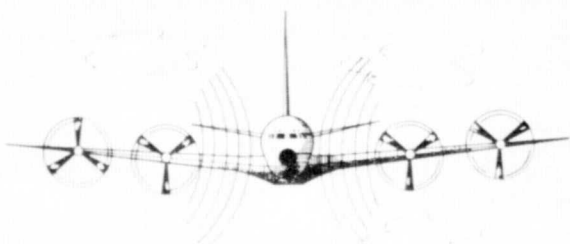
100-111-111-111 (3)
111-111-111

ADVANCED TURBOPROP PROGRAM



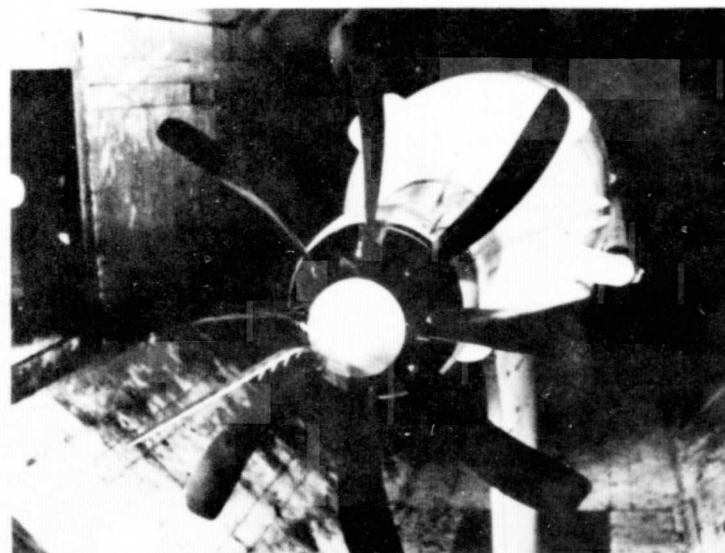
COMMUNITY NOISE REDUCTION

- PROPELLER DESIGN SUCH AS SWEPT TIP BLADES



CABIN NOISE ATTENUATION

- ADVANCED LIGHTWEIGHT MATERIALS FOR FUSELAGE TREATMENT



WIND TUNNEL TESTS

- DEFINE PROPELLER NOISE LEVELS
- DEVELOP ANALYTICAL MODELS FOR IMPROVED ACOUSTIC PREDICTION

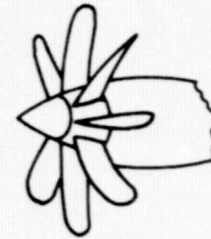
ANALYSIS

- AERODYNAMIC/ACOUSTIC/STRUCTURAL TRADES

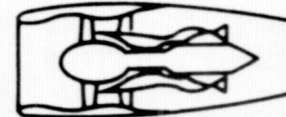
Figure 4

AIRCRAFT ENERGY EFFICIENCY PROGRAM FY1978 NEW EMPHASIS

ADVANCED TURBOPROP - PHASE I



ENERGY EFFICIENT ENGINE - II



ENERGY EFFICIENT TRANSPORT - II

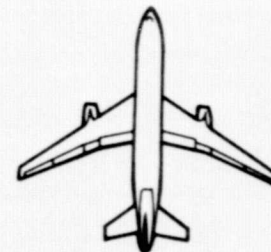
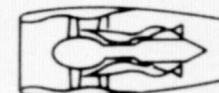


Figure 5

ENERGY EFFICIENT ENGINE PROGRAM



FISCAL YEAR							
1976	T	1977	1978	1979	1980	1981	1982

ENGINE DEFINITION STUDIES
AND COMPONENT DESIGN

PHASE I

FULL-SCALE COMPONENT TEST

- COMPRESSOR
- COMBUSTOR
- HP TURBINE
- FAN
- LP TURBINE
- MIXER/NACELLE

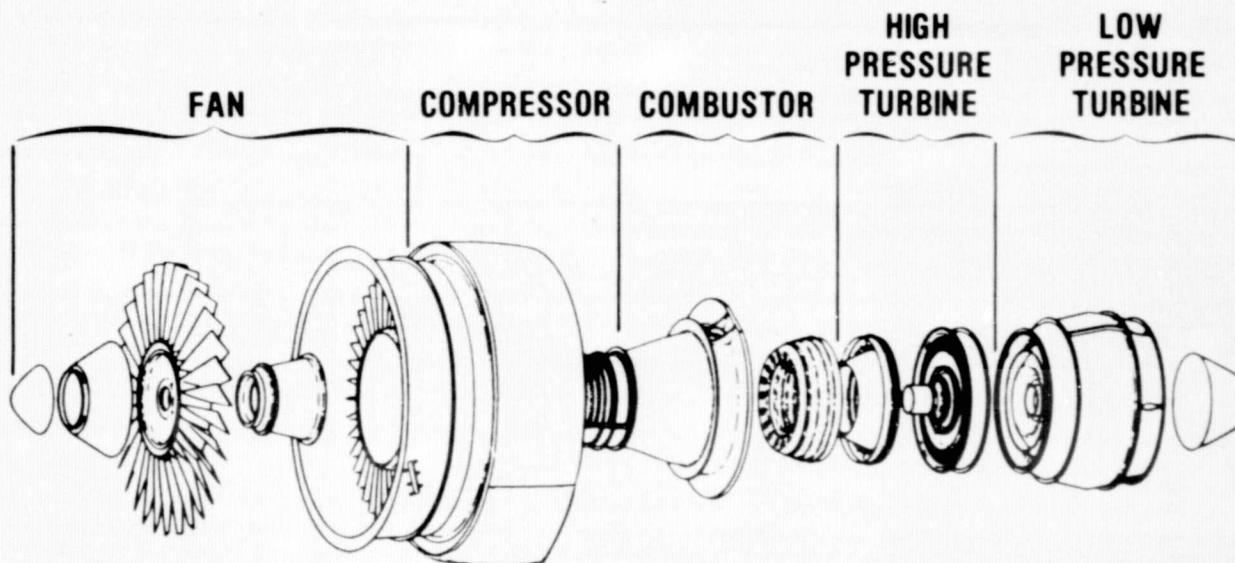
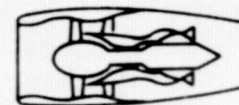
PHASE II

CORE
DESIGN AND TEST
• COMPONENT INTEGRATION
& REFINEMENT

CORE/LOW SPOOL
DESIGN AND TEST
• SYSTEM INTEGRATION

Figure 6

ENERGY EFFICIENT ENGINE PROGRAM FULL SCALE COMPONENT TEST



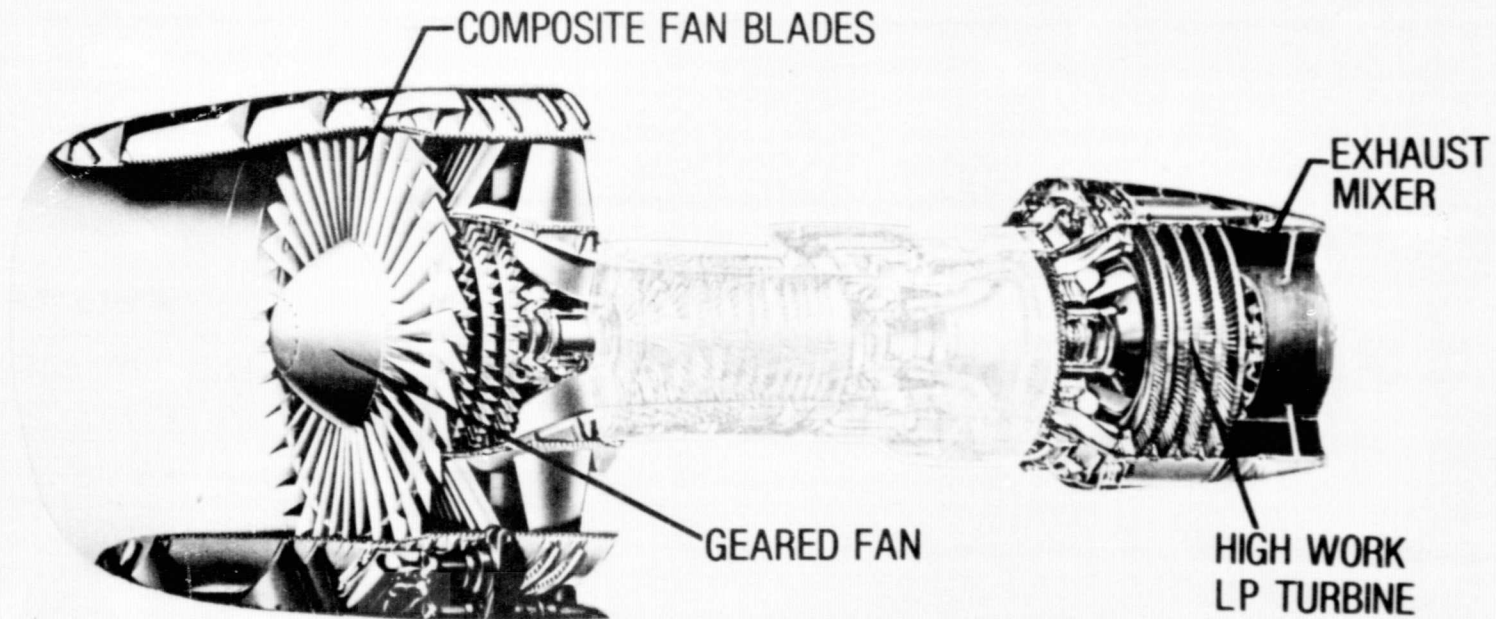
CORE AND LOW SPOOL COMPONENT PERFORMANCE EVALUATION

- AERODYNAMICS
- HEAT TRANSFER
- NOISE/EMISSIONS
- MECHANICAL INTEGRITY
- DURABILITY
- SEALS/CLEARANCE CONTROL

Figure 7

NASA HQ RJ77-1186 (3)
12-29-76

ENERGY EFFICIENT ENGINE PROGRAM CORE/LOW SPOOL DESIGN AND TEST



FULL SCALE SYSTEM INTEGRATION TESTS

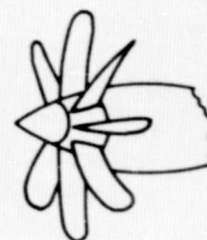
- CORE AND LOW SPOOL COMPONENTS

Figure 8

AIRCRAFT ENERGY EFFICIENCY PROGRAM

FY1978 NEW EMPHASIS

ADVANCED TURBOPROP - PHASE I



ENERGY EFFICIENT ENGINE - II



ENERGY EFFICIENT TRANSPORT - II

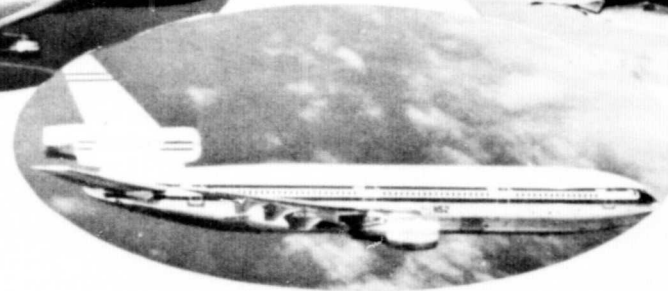
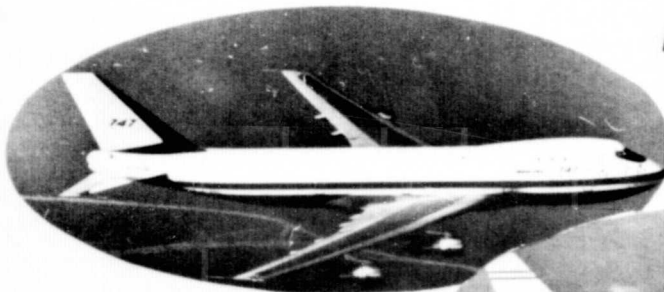


Figure 9

ENERGY EFFICIENT TRANSPORT PROGRAM SELECTED CONCEPTS EVALUATION



DERIVATIVE AIRCRAFT APPLICATIONS



WING GEOMETRY MODIFICATIONS

- WINGLETS/WING TIP EXTENSIONS

ACTIVE CONTROLS TECHNOLOGY

- GUST/MANEUVER LOAD/ELASTIC MODE CONTROL

PROPULSION SYSTEM INTEGRATION

- NACELLE/PYLON/WING INTERFERENCE

FLIGHT TEST OF MODIFIED TRANSPORT AIRCRAFT

DESIGN, CONSTRUCTION, FLIGHT EVALUATION OF CERTIFICATABLE SYSTEM

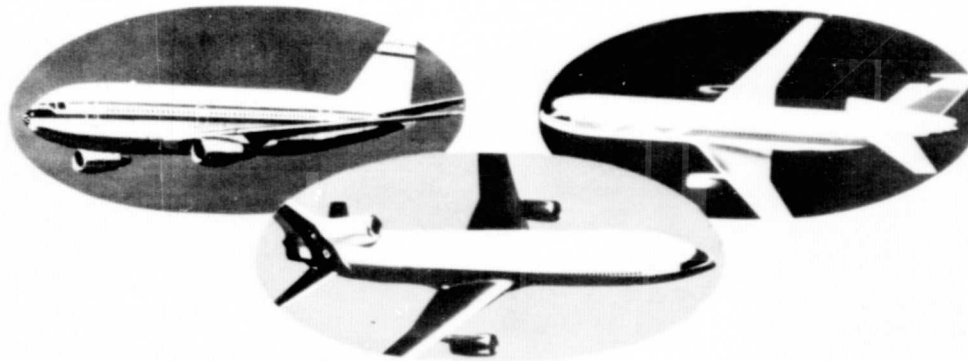
LONG DUCT NACELLE FULL-SCALE GROUND TESTS, FLIGHT EXPERIMENTS

Figure 10

ENERGY EFFICIENT TRANSPORT PROGRAM SELECTED CONCEPTS EVALUATION



NEW AIRCRAFT APPLICATIONS



WING GEOMETRY IMPROVEMENTS

- SUPERCRITICAL WING/HIGH LIFT DEVICES

ACTIVE CONTROLS TECHNOLOGY

- AUGMENTED LONGITUDINAL STABILITY

ADVANCED FLIGHT CONTROLS

- MAXIMUM BENEFIT ACTIVE CONTROLS

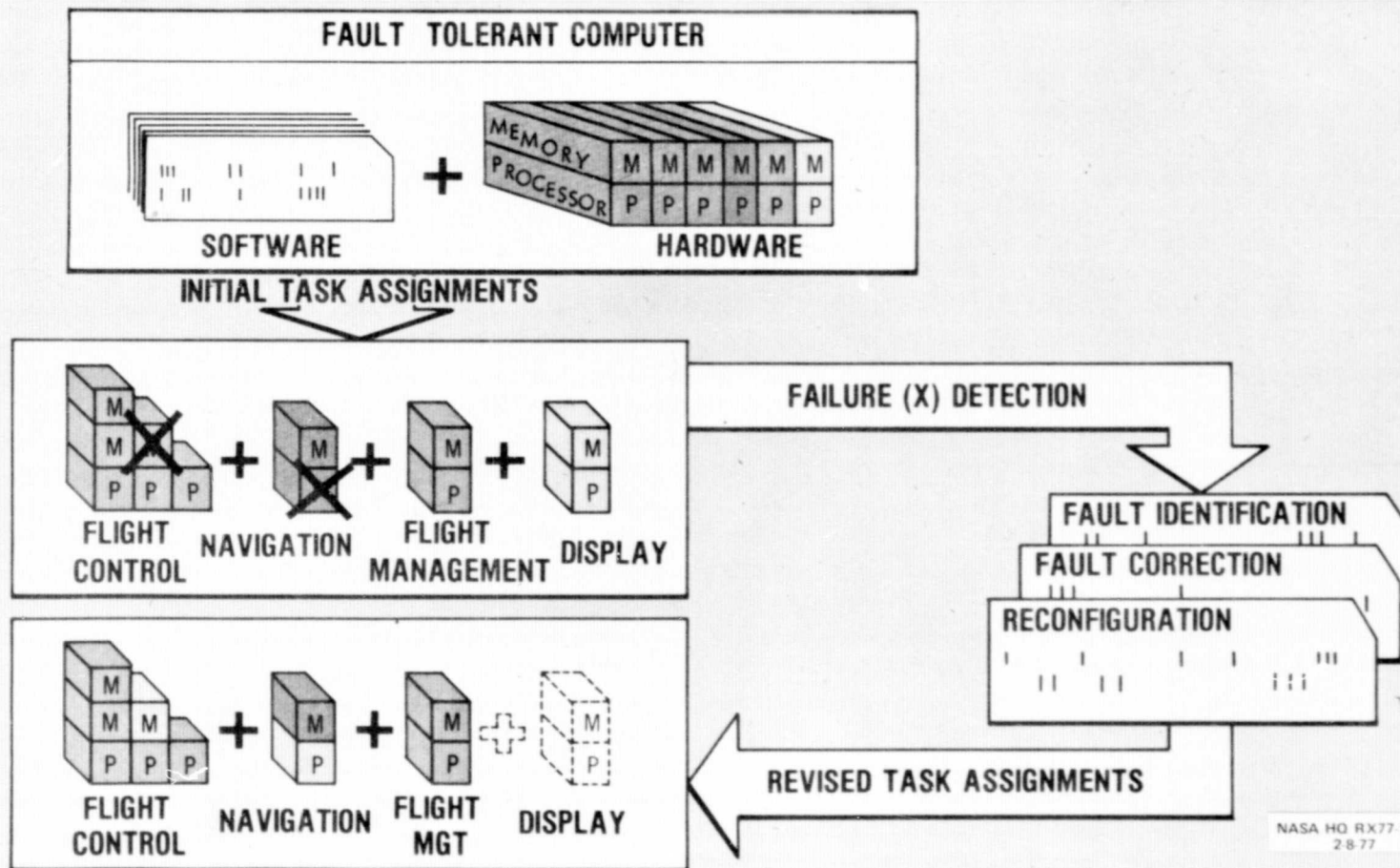
WIND TUNNEL VALIDATION, STRUCTURAL / AERODYNAMIC TRADES

DESIGN AND FLIGHT TEST REDUCED SIZE HORIZONTAL TAIL

ADVANCED CONTROL SYSTEM DESIGN, DEVELOPMENT, TEST

Figure 11

ENERGY EFFICIENT TRANSPORT PROGRAM ADVANCED COMPUTER SYSTEM



NASA HO RX77-1563 (3)
2-8-77

Figure 12

AIRCRAFT ENERGY EFFICIENCY PROGRAM

FY 1978 FUNDING (\$M)

	ONGOING PROGRAMS	AUGMENTATION	ACEE TOTAL
ENGINE COMPONENT IMPROVEMENT	10.0	—	10.0
ENERGY EFFICIENT ENGINE			18.5
PHASE I	8.5		
PHASE II	—	10.0	
TURBOPROPS - PHASE I	—	2.0	2.0
ENERGY EFFICIENT TRANSPORT			13.4
PHASE I	9.0	—	
PHASE II		4.4	
LAMINAR FLOW CONTROL	1.2	—	1.2
COMPOSITE PRIMARY STRUCTURES	<u>25.1</u>	—	<u>25.1</u>
TOTAL	53.8	16.4	70.2

Figure 13

SECTION I-D. SUPERSONIC CRUISE AIRCRAFT RESEARCH

In September 1976, the House of Representatives' Subcommittee on Aviation and Transportation R&D of the Committee on Science and Technology invited industry to testify on the progress of the Supersonic Cruise Aircraft Research (SCAR) program and the relationship of the program to accelerating technology availability for this class of aircraft. A review of the testimony indicated that, in the industry's view, and in the Subcommittee's view, Variable Cycle Engine (VCE) technology is the critical pacing technology needed to assure that economic and environmental requirements for future supersonic cruise aircraft can be met. Industry also indicated that research in structures, materials, aerodynamics and advanced control techniques must continue until technology readiness has been established.

During a four-day conference on SCAR technology held at the Langley Research Center in November 1976, some fifty papers discussing all aspects of SCAR technology were presented to and discussed by an audience of almost 300 technical specialists. Progress in the program from its inception in 1972 was seen as impressive with increases in range from 3000 to 4500 nautical miles while achieving a payload three times that of Concorde, and with total operating costs projected to be within 10% of current wide-body aircraft, all of this while meeting environmental constraints.

With these potentials for progress identified, there still remains a very significant amount of technology to be developed. The activities we plan in the FY 1978 program are necessary next steps.

Variable Cycle Engine Technology

As previously mentioned, a VCE is the pacing technology element and is required in all aircraft configurations being studied in the SCAR program. This is a new propulsion concept, the basic technology for which is available only in the United States. It is complex and will be expensive to develop, but, in our view, it is absolutely necessary to assure efficient and economical operation of future aircraft of this class.

The significance of engine cycle flexibility to the concept of a truly efficient supersonic cruise aircraft

cannot be overemphasized. The estimated improvement in specific fuel consumption of 20 to 30% during all subsonic flight conditions, which consume a large fraction of the total fuel burned on each flight, obviously strongly influences the economic performance. Variable cycle engines inherently provide significant noise reduction and we are confident that noise levels equivalent to B-747 (FAR-36) can be achieved.

Since supersonic cruise aircraft must simultaneously meet essentially contradictory performance and environmental requirements, our variable cycle engine critical component test program is directed to solutions which match these requirements. The major problem for the propulsion system on this type of aircraft is that it must functionally accommodate at least two distinct modes of operation: 1) a high airflow, low jet velocity turbofan-like mode for low noise takeoff and efficient subsonic cruise; and 2) a turbojet-like, higher jet velocity, lower airflow mode for supersonic cruise. The rationale for a variable cycle engine (VCE) is its ability to provide a performance match at various operating conditions while also satisfying environmental constraints. It should be noted here that "variable cycle" engines also offer promise for military missions. However, the military missions cannot compromise performance to meet stringent noise and pollution reduction constraints which must characterize a civil version, and the component technology which we are working on is necessarily different from that for military applications.

The propulsion studies conducted by the Pratt & Whitney and General Electric companies to identify promising variable cycle engines have resulted in two quite different concepts: the Variable Stream Control Engine of Pratt & Whitney and the Double Bypass Engine of General Electric. The mechanization of these two concepts is quite different and both are very complex, but the principles on which they operate to reduce noise and improve fuel consumption are similar. These principles are illustrated in Figure 1. Shown here are two engine cycles, a standard turbojet and a typical variable cycle engine, the latter in its three different modes of operation: takeoff, subsonic cruise and supersonic cruise. The chart illustrates the effects of nozzle characteristics on specific fuel consumption and noise at takeoff. Nozzle characteristics are given in terms of stream velocity and stream temperature at the exit. The baseline turbojet cycle has a constant velocity and temperature profile across the nozzle exit. In a variable cycle engine the velocity of the stream

varies across the nozzle. At takeoff such an engine cycle has a higher flow velocity and temperature in the outer annulus of the nozzle. It is this coannular effect which reduces noise at takeoff from 120 to 108 EPNdB. In the subsonic cruise mode the flow schedules between the inner core and outer annulus are inverted with higher temperatures in the inner nozzle section so that the engine performs as a turbofan with a major reduction in specific fuel consumption as compared to a straight turbojet.

In the supersonic cruise mode, the velocities and temperatures are essentially uniform and the cycle operates as a turbojet but without the very high temperatures required of an afterburning engine. In this flight regime there will be a small percentage savings in fuel consumption over that of a straight turbojet, but the amount will be determined by the specific engine design.

Such VCE concepts offer significant performance benefits combined with the potential of meeting future noise and pollution requirements. Achievement of these objectives is clearly dependent on the efficient functioning of the engine components unique to such cycles.

An experimental VCE critical components program (Figure 2) is under way to develop and evaluate the components which represent the major technological risks and uncertainties at this time. Aero/acoustic investigations will continue through FY 1979 with coannular/annular inverted exhaust gas profile nozzle evaluations using small-scale models. Primary emphasis will be placed on acoustic performance.

A front block fan for the G. E. concept will be designed, fabricated and rig tested to demonstrate efficient operation over a wide range of flow conditions.

Duct burner design concepts are being screened and segments of promising designs will be fabricated and rig tested by P&W to establish performance and emission levels.

Finally, with the proposed increase in funding, larger scale tests of the critical components of the G. E. and P&W cycles would be conducted in FY 1978 to establish the almost full-scale acoustic characteristics of these engine cycles. The critical components, such as nozzles, duct burners, and front fan modifications, would be tested using existing high technology engine cores as the gas generators. Temperature, pressure and flow conditions which closely simulate those for a full-scale engine would provide the data required for a future decision to proceed with a variable cycle experimental engines program.

SCAR Systems and Disciplinary Research

While the proposed program emphasizes VCE technology in FY 1978, continued research is also still necessary and will be sustained in systems integration studies and the related disciplinary research programs.

Systems Integration Studies

Three systems integration study contracts and an in-house effort now under way will be completed during FY 1978. These studies will analyze major subsystem integration techniques and/or problems inherent in each of the candidate airframe configurations. The four configurations being studied by four different teams are illustrated in Figure 3. The Boeing Company blended delta-wing Mach 2.4 design is illustrated on the top left. The McDonnell Douglas Corporation Mach 2.2 design is shown on the top right. The Lockheed Aircraft Corporation engine over/under the wing Mach 2.55 design is illustrated at the lower left. The NASA Langley baseline Mach 2.7 arrow wing is shown at the lower right.

These studies will provide NASA and industry detailed analysis and sensitivity assessments of the somewhat different technologies required for each configuration. Because the performance of supersonic aircraft is so dependent upon the optimization of all subsystems and is so sensitive to the interaction and trade-offs of various technologies, the SCAR program has continuously emphasized the conduct of these studies, so that only the highest payoff technologies are pursued within the limited scope of the program. These studies are the basis for confidence in achieving the goals of the program.

Aerodynamics

There are two specific disciplinary research activities planned for FY 1978 for which augmentations are requested. The first is a proposed expansion of the aerodynamics research activities. While major progress has taken place in drag reduction such that the lift-to-drag ratio at supersonic speeds can be increased by as much as 30%, the systems integration studies have indicated that substantial additional improvements in aerodynamic performance are possible in several remaining areas. These areas include improved low-speed operation by refinement of wing leading and trailing edge contours, further reductions in transonic drag by improved engine nacelle/airframe integration, and outboard wing camber and thickness changes to reduce structural weight penalties.

These refinements and improvements would be pursued beginning in FY 1978 through a series of wind-tunnel model tests. Several new and somewhat larger wind-tunnel models incorporating necessary refinements would be constructed and tested at critical low, transonic and supersonic speed conditions. Each configuration would be optimized to provide the best compromise over all flight speeds.

Structures

The second area is a proposed expansion of the structures and materials program in superplastic forming (SPF) and diffusion bonding (DB) of large titanium structural components. This very recent technology was developed by Rockwell International in the Air Force B-1 program.

The titanium superplastic forming and diffusion bonding process is illustrated schematically in the next chart (Figure 4). Very complex structural elements may be produced when titanium is formed under conditions of pressure and temperature such that the material flows in a plastic fashion in the tooling molds. Diffusion bonding may be included in the process as illustrated when, for example, a preplaced attachment clip and the main piece being formed are both included in the tooling mold. The net result is a major savings in the amount of titanium used and a large reduction in the number of fasteners and secondary operations. This technology, when applied to long-life commercial aircraft applications, indicates a structural weight reduction of 14% over other forming and fabrication processes. However, the surprising result is the potential reduction of 30% in airframe cost. This cost reduction feature is particularly important to civil/commercial aircraft designs.

To further establish the significance of superplastic forming and diffusion bonding technology, five separate structural areas--two on the fuselage and three on the wing--were selected for a study by Rockwell International. The arrow-wing Boeing SCAR designs for these areas were provided as the baseline reference. Each area was redesigned to identical load conditions using SPF/DB techniques. Estimates of SPF/DB design indicate that up to 65% of fuselage and 61% of wing production costs may be saved. When the aircraft design is resized to reflect the component weight reduction in the full structure, reductions of 25% in the airframe weight with concurrent fabrication and assembly cost reductions as high as 50% are anticipated. Rockwell International is now conducting a similar study under a Lockheed subcontract to evaluate the

potential of this technology to components of their SCAR arrow-wing aircraft system.

The FY 1978 activity in superplastic forming and diffusion bonding of titanium will be the initial effort in a continuing three-phase program to fully characterize and define this technology for application to long service-life commercial aircraft structures and will complement a large effort by the Air Force to characterize this technology for military aircraft applications. The first phase is directed to verification of preliminary design methods for various structural components such as wing panels, fuselage sections and nacelle access panels. The second phase would be directed to determination of production design criteria, followed by the final phase devoted to validation of strength and life requirements in typical large structural components.

Fiscal Resources

During FY 1978, we propose to increase the funding levels for both SCAR Discipline Research and the Variable Cycle Engine Component Test Program as shown in Figure 5. The Discipline Research increase is provided in this level of effort program to compensate for continuing inflationary effects and to permit the program expansions just described. The proposed Variable Cycle Engine Component Test Program increase of \$3.1M is to provide the funding level necessary to conduct the critical component testing as expeditiously as possible for this pacing technology.

Summary

In the spring of 1976, the House of Representatives' Subcommittee on Aviation and Transportation R&D of the Committee on Science and Technology held a series of hearings on the "Future of Aviation." As a result of one of the findings (No. 12), the Subcommittee recommended:

"It is clearly in the national interest for the U. S. to build an environmentally acceptable, fuel efficient and economically viable supersonic air transport aircraft. Government action in the near term should be aimed at accelerating the technology availability date for such a project and at reducing barriers to development by the private sector."

It is suggested that the NASA SCAR program is providing technology advancements in consonance with the recommendations of the Subcommittee. With continuing and sustained

support, we are confident that this technology, when fully verified, can provide the basis for U. S. decisions on a commercially competitive, environmentally compatible, second-generation supersonic cruise aircraft.

SCAR

VELOCITY EFFECTS ON NOISE AND PERFORMANCE

TURBOJET

	NOZZLE CHARACTERISTICS		SPECIFIC FUEL CONSUMPTION		NOISE AT TAKEOFF
	VELOCITY FT/SEC	TEMP °F	SUBSONIC	SUPERSONIC	
BASELINE TURBOJET WITH AFTERBURNER 	3000	2900	1.5	1.4	120 EPNdB

VARIABLE CYCLE ENGINES (TYPICAL)

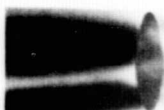
TAKEOFF 	OUTER	2900	2600	—	—	108 EPNdB
	INNER	1700	1250			
	OUTER	2900	2600			
SUBSONIC CRUISE 	OUTER	1850	240	1.0	—	EQUAL TO B-747
	INNER	2000	900			
	OUTER	1850	240			
SUPERSONIC CRUISE 	OUTER	3700	1350	—	1.4	NOT APPLICABLE
	INNER	3450	1420			
	OUTER	3700	1350			

Figure 1

SCAR

VARIABLE CYCLE ENGINE CRITICAL COMPONENT TECHNOLOGY

FY 76	T	77	78	79	80
-------	---	----	----	----	----

**AERO/ACOUSTIC
MODEL TESTS**



**FRONT BLOCK FAN
RIG TESTS (GE)**



**DUCT BURNER RIG
TESTS (P&W)**



**LARGE SCALE CRITICAL
COMPONENT FABRICATION
& TESTING**



◇ ACOUSTIC TESTS

NASA RA77-1280(3)
1-25-77

Figure 2

SCAR

ADVANCED SUPERSONIC CRUISE AIRCRAFT CONFIGURATIONS

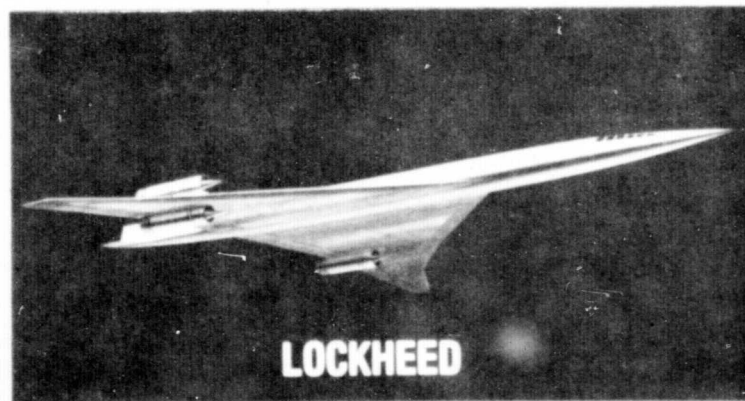
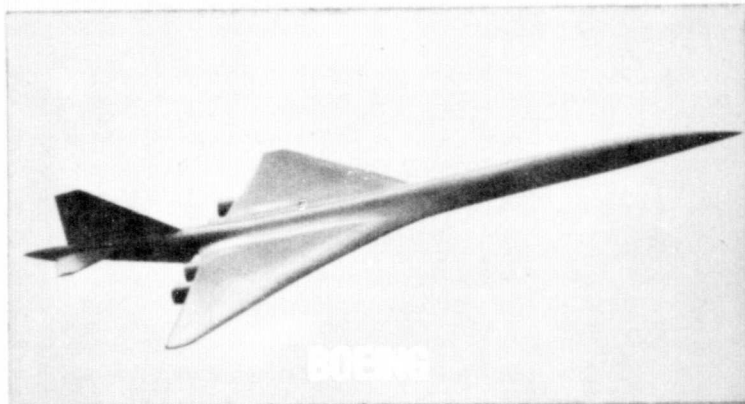


Figure 3

NASA CR-100 (1971)

SCAR

SUPERPLASTIC FORMING/DIFFUSION BONDING SEQUENCE

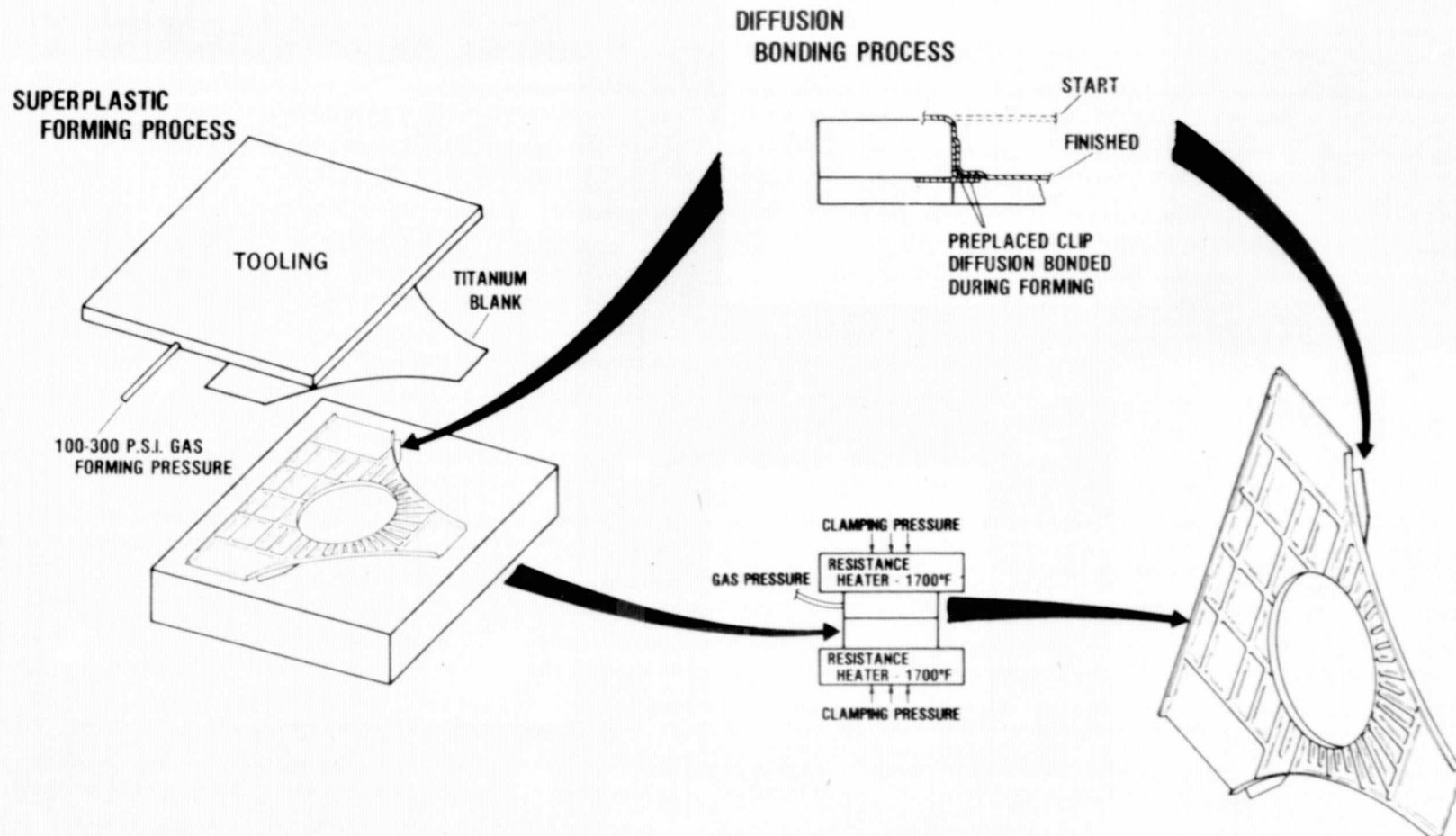


Figure 4

SCAR

SCAR/VARIABLE CYCLE ENGINE PROGRAMS (\$M)

	FY 1977	FY 1978
● SCAR DISCIPLINE RESEARCH	8.0	9.0
● VARIABLE CYCLE ENGINE COMPONENT TEST PROGRAM	<u>3.1</u>	<u>6.2</u>
TOTAL	11.1	15.2

SECTION II-A. INTRODUCTION

Within NASA it is the responsibility of the Office of Aeronautics and Space Technology (OAST) to provide the advanced technology that other NASA program offices (and industry) require so that future space programs can be effectively selected, planned, and successfully accomplished. This technology evolution process is a complex effort requiring the coordinated application of the best scientific and engineering minds and a broad spectrum of facilities at all of our research centers.

That the OAST efforts in the past have been successful can best be appreciated by reviewing briefly some major OAST technology contributions to two highly complex NASA space programs; namely the Viking Mars Exploration and the Space Shuttle.

Figure 1 illustrates the operational mission profile of the Viking Mars Orbiter and Lander. On this figure are identified eight major OAST technology contributions. Each required a high degree of inventiveness to enable the Viking program to achieve the successes that it has. One of these--the three color camera on the two Landers will be discussed. The extremely clear photographs that have been made of the Mars surface by these cameras have been seen by all. This camera system, used to record all color and black and white pictures of the Martian surface, is a flight version of a system first developed by OAST in 1969. The camera has spatial resolution varying from a few millimeters close to the camera to approximately one meter at the Martian horizon. Recent studies indicate that auxiliary optics could be added to the camera system to improve its resolution capabilities significantly.

Figure 2 illustrates the total Space Shuttle system and identifies six major OAST contributions. Again, one of these--the reusable surface insulation, otherwise known as the Thermal Protection System (TPS)--will be discussed. The success of the reusable Shuttle Orbiter is obviously dependent on the ability of the Shuttle surfaces, especially the lower, to survive the high reentry temperatures and be quickly reusable with a minimum of refurbishment. The original insulation coating material selected for the Shuttle failed to achieve the desired performance of withstanding a temperature of 2300°F for a 100-mission lifetime. The coating cracked after 10 to 15 simulated missions. However, at our Ames Research Center an advanced in-house program was developing

an insulation technology that was required for application to advanced vehicles. It was found that this parallel development could readily provide a coating for the insulation that would meet the stringent Shuttle temperature and life requirements and at less cost. It is now being used on the Shuttle Thermal Protection System.

Providing NASA with the capability to accomplish future space objectives is a major responsibility since, if the research and technology are not advanced and technological breakthroughs are not made, the future opportunities cannot become reality. For this reason a great deal of attention is devoted to space technology planning. Figure 3 illustrates the OAST methodology which permits systematic planning of the continuing and evolving space R&T efforts. A brief description of this process in the context of our FY 1978 planning cycle will be useful in setting the stage for the proposed FY 1978 program that will be described shortly.

OAST planning began with a review of potential future space missions, and the identification of three basic themes which typify the needs for important advances in space technology. Figure 4 illustrates these three basic themes. They are:

1. Industrialization in Space, which includes such possibilities as:
 - a. Space Construction and Manufacturing;
 - b. Space Power Platforms; and
 - c. Advanced Space Propulsion and Fully Reusable Transportation Systems.
2. Global Services from Space, including:
 - a. Advanced Remote Sensing of the Environment; and
 - b. Worldwide Communications and Navigation Services.
3. Exploration of Space, involving:
 - a. Solar System; and
 - b. Search for Extraterrestrial Intelligence.

The advanced technology and system studies and the OAST Space Technology Working Groups and Workshops, shown in the second level blocks of Figure 3, are primary planning tools through which future programs, missions, and technologies (both planned and forecast) are examined. Required research and technology are defined, gaps in the ongoing R&T programs are identified, and alternative means of satisfying the needs are evaluated. The alternative approaches are assessed in terms of the relative cost, risk, and benefits, with particular emphasis on the major items which would drive technology requirements. Plans are then developed for new initiatives in the R&T base activities, systems technology projects, and flight experiments. This is the process, for example, that led to the OAST Orbiter Experiments Program.

The advanced studies have covered such topics as sample return strategies, technologies for SETI (Search for Extraterrestrial Intelligence), advanced Earth-to-Orbit transportation technology, solar electric propulsion, solar sailing feasibility, data compression technology, and space industrialization concepts. They have also examined the opportunities for application of projected technology advances such as onboard data processing, planetary propulsion, large antennas, machine intelligence, automation/teleoperators, high-pressure engine cooling, figure and attitude control, kilowatt/megawatt power, end-to-end data management, large-area structures, and sensor-integrated processing. Key technology needs and opportunities identified in the advanced studies were considered in preparing the current research program.

To supplement these planning processes and focus special emphasis on the three basic themes, a Space Theme Workshop was convened in April 1976 at the Langley Research Center. The workshop then identified the key research and technology requirements needed for the specific theme missions. These included significant technology needs in space, power, propulsion, materials, structures and electronics, as shown in Figure 5.

Finally, the Space R&T Base Program was critically examined during the workshop to identify those tasks which either enhanced or enabled a theme and to identify new and promising R&T candidates which should be incorporated into the base to meet essential long-range goals. In many instances, the existing base program provided enhancing or enabling theme-related technologies. As might be expected, however, some R&T base programs would have to be expanded or accelerated to meet theme objectives. Potential new initiatives for FY 1978, as well as future years, were also identified.

In summary, an effective, systematic planning methodology has been utilized in generating OAST Space R&T activities. Using the themes, the Outlook for Space Report, and Congressional guidance as overall mission guidelines, the advanced studies and the workshops have resulted in identification of several key space technology needs as identified in Figure 5. The proposed OAST program described in Section II-B will address the most important and time-critical technologies. In addition, the OAST Orbiter Experiments Program, which will receive special emphasis in FY 1978, is described in Section II-C.

This testimony provides a good overview of the OAST space programs and planning for FY 1978. This program involves some very interesting and challenging technical work and contains the activities required for the new and exciting concepts of the future to become reality. It is focused on meeting near-term and long-range goals evolved from our planning effort. The program supports advanced research with high potential payoff, and is contributing significantly to maintaining our Nation's technological leadership in the world.

MAJOR JAST TECHNOLOGY CONTRIBUTIONS TO VIKING

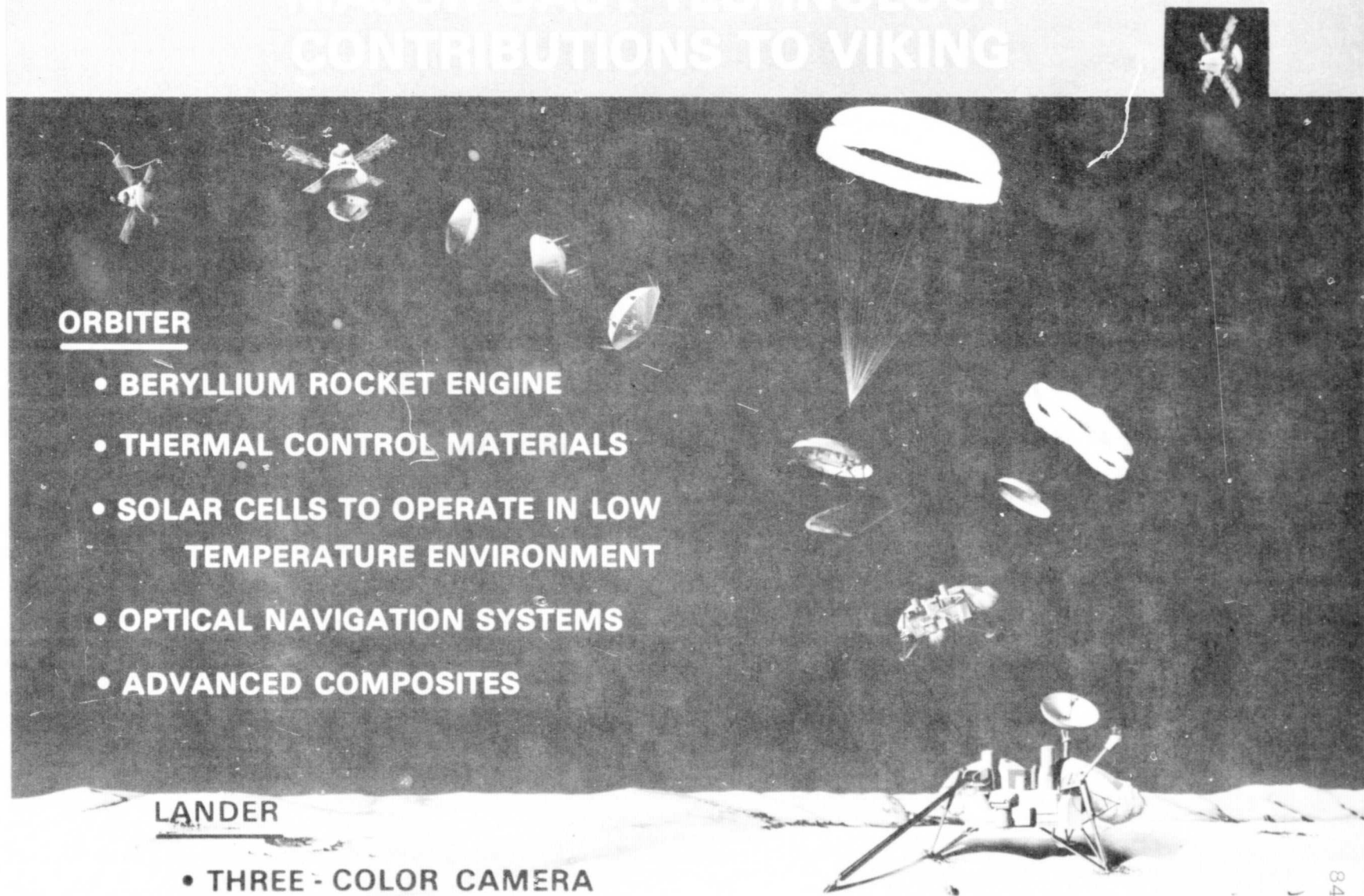
ORBITER

- BERYLLIUM ROCKET ENGINE
- THERMAL CONTROL MATERIALS
- SOLAR CELLS TO OPERATE IN LOW TEMPERATURE ENVIRONMENT
- OPTICAL NAVIGATION SYSTEMS
- ADVANCED COMPOSITES

LANDER

- THREE - COLOR CAMERA
- ENGINE CATALYST
- STERILIZABLE NI-CD BATTERIES

Figure 1



NASA HQ RX77-965(3)
12-7-76

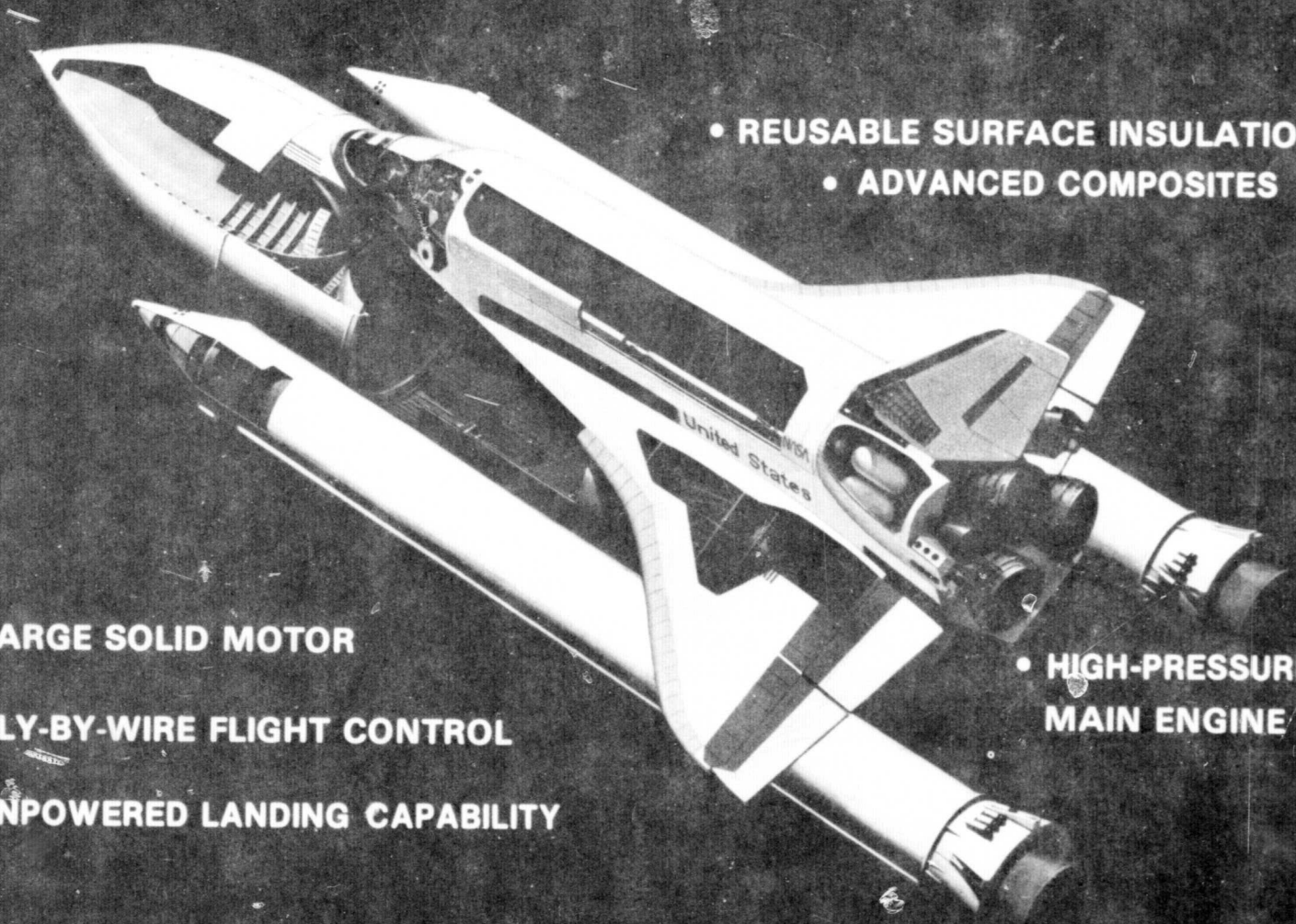
- 
- REUSABLE SURFACE INSULATION
 - ADVANCED COMPOSITES
 - LARGE SOLID MOTOR
 - FLY-BY-WIRE FLIGHT CONTROL
 - UNPOWERED LANDING CAPABILITY
 - HIGH-PRESSURE MAIN ENGINE

Figure 2

SPACE TECHNOLOGY PLANNING METHODOLOGY

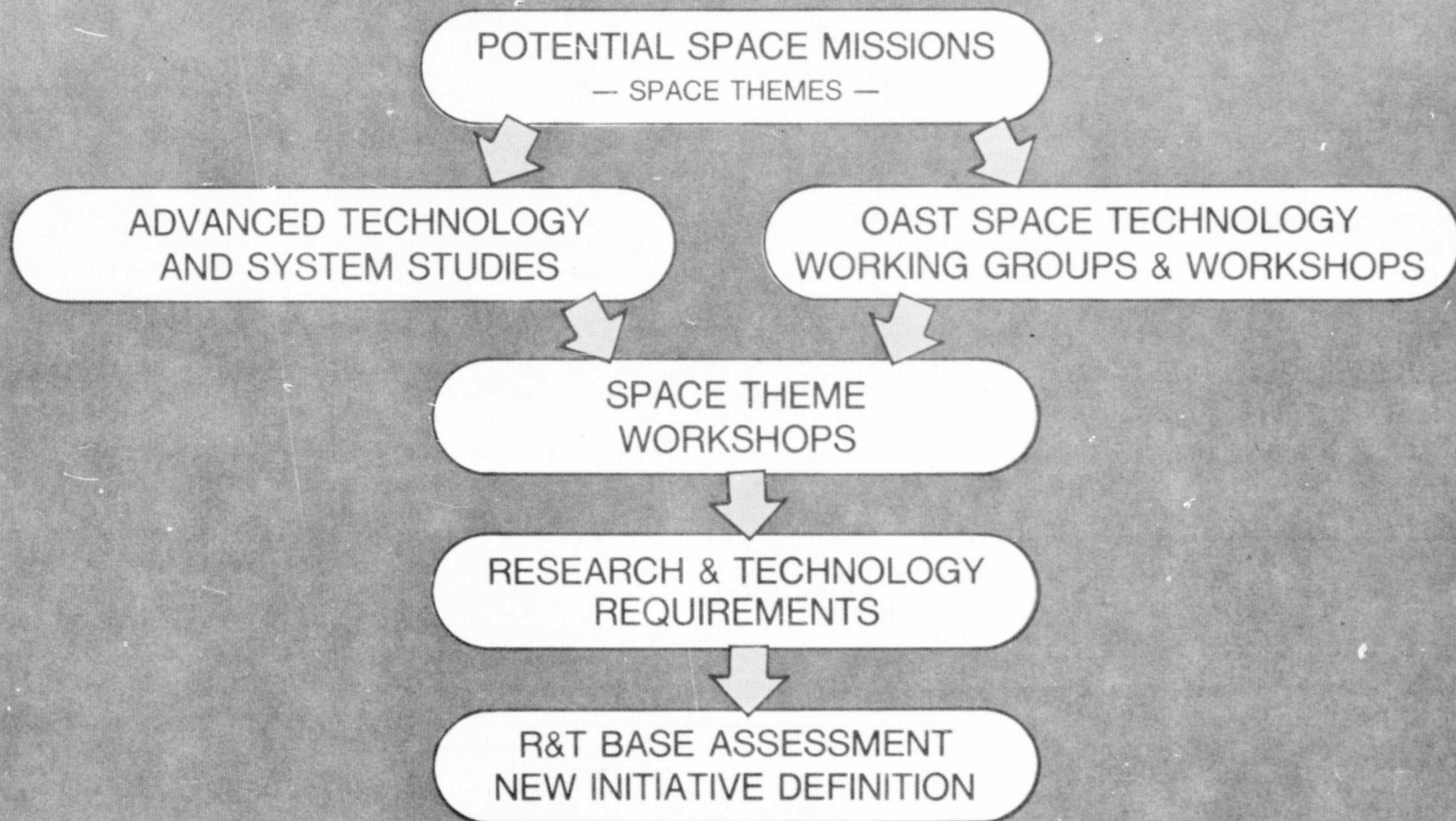
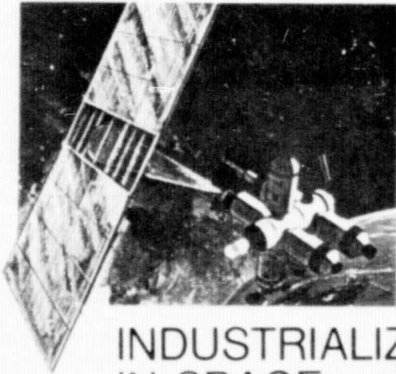
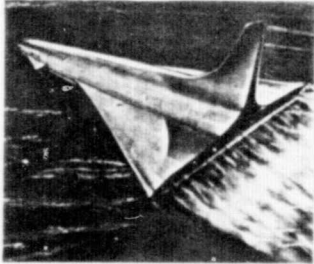


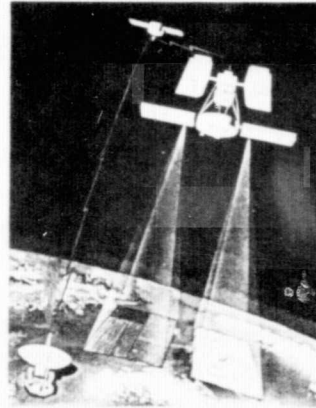
Figure 3

OAST SPACE TECHNOLOGY THEMES

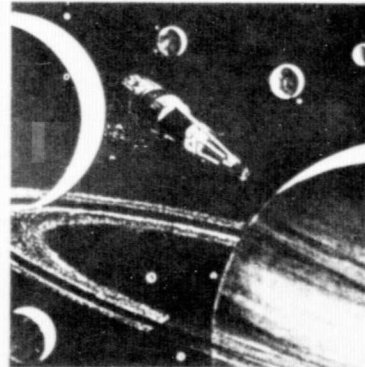
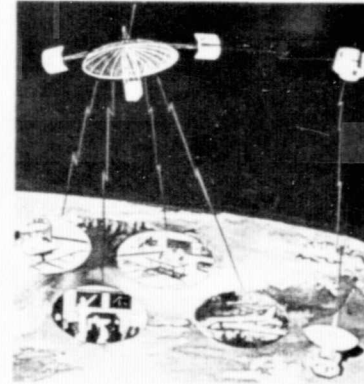


INDUSTRIALIZATION
IN SPACE

NASA HQ RX76-3998(3)
REV-1-11-77



GLOBAL SERVICES
FROM SPACE



EXPLORATION
OF SPACE

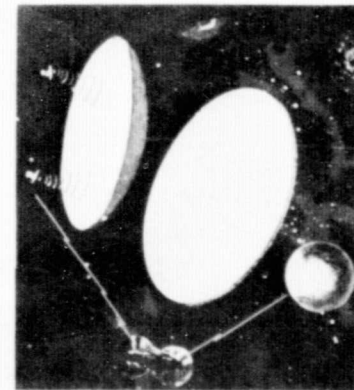


Figure 4

KEY SPACE THEME TECHNOLOGY NEEDS

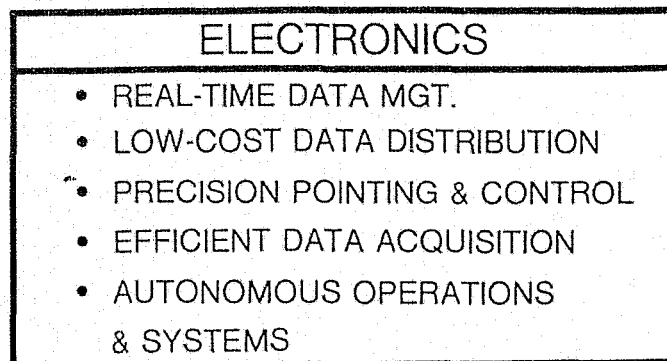
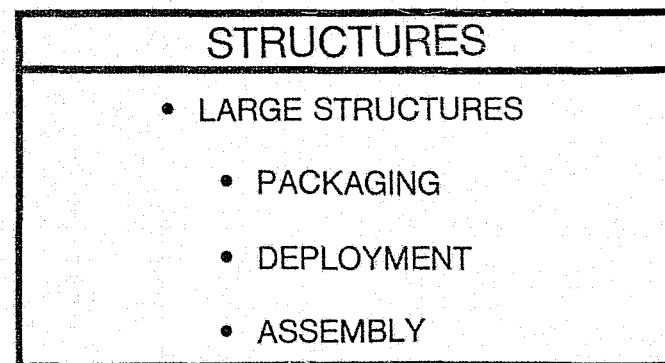
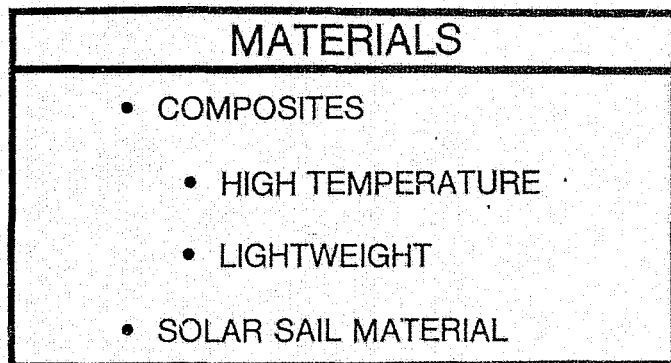
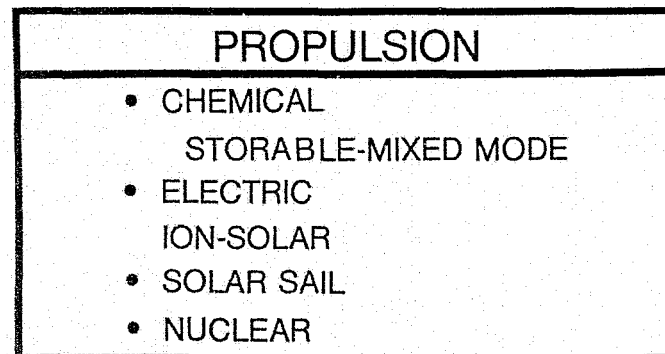
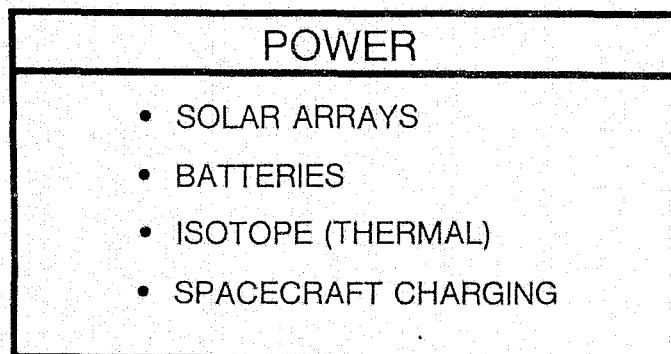


Figure 5

SECTION II-B. FY 1978 PROGRAM SUMMARY

A brief summary of the proposed OAST FY 1978 Space research and technology budget is shown in Figure 1. A substantial increase over 1977 is noted, in the overall budget request and specifically the increases in the Systems Technology Programs and the Experimental Programs. To a great degree, these increases are a reflection of the maturing of the individual technologies so that they can be assembled and demonstrated as systems and experiments. In the area of the Systems Technology Programs, for example, activities in space materials and structures technology are being increased because it is clear that this technology is a necessary ingredient for many potential future space programs. In the area of Experimental Programs, experiments to be conducted on the Space Orbiter are rapidly beginning to take shape as a viable source of new technology. This program is discussed in more detail in Section II-C. The Low Cost Systems Program goes a step beyond technology readiness to further reduce the cost of space systems by standardization of components and subsystems.

The following is a brief overview of what is being planned in the following space technology areas: Power, Propulsion, Materials, Structures and Electronics.

SPACE POWER

The Space Power Technology Program is essential to all future space systems. As missions become more demanding, so too do space power needs. To provide power for the future exploration and development of space will require new, higher power and longer life energy systems at improved specific mass and cost.

One of the major goals in space solar power technology, as shown in Figure 2, is to develop the technology for and demonstrate a high-power photovoltaic space solar array with 100 watts of electrical power output per pound of weight. This technology is a three- to fourfold improvement over our near-term capability. A significant stride toward this goal has been achieved with the development of thin (2' to 3 mil) silicon solar cells at one-fifth the mass of current flight solar cells. In FY 1978 work will continue toward the improvement of the efficiency of these thin cells. This technology is fundamental, not only to the relatively near-term thrust of extending

performance capability of solar electric propulsion, but also for space industrialization and other future concepts such as the satellite power station currently under study. Significant advances have also been made in gallium-arsenide solar cell research which offers the promise of improved performance in efficiency and resistance to environmental degradation.

A major component of a power system is the battery. It is one of the most significant factors in low-Earth-orbit satellite mass and life limitations. The advanced battery technology effort is aimed at the goal of doubling life and power density of nickel cadmium batteries by 1980. In FY 1978, battery component technologies will be evaluated for fabrication and test in FY 1979.

Isotope power systems are needed for a variety of missions for which solar power is impractical. At present they are both costly and heavy. In a joint program with ERDA, OAST is developing critical Brayton System components as shown in Figure 3 for a possible future system in the 2-kilowatt range, which promises substantial cost and mass savings. Key components of this system will be delivered to ERDA in FY 1977 for initiation of ground testing. During FY 1978, support for this activity will continue.

In addition to component technology, OAST is investigating environmental effects on power systems and spacecraft charging. During FY 1978, analytical models developed under the joint NASA/Air Force Spacecraft Charging Program (to provide design criteria, techniques, and test methods to insure control of absolute and differential charging of spacecraft surfaces) will be correlated with flight test data from the Air Force Spacecraft Charging at the High Altitudes (SCATHA) Satellite.

SPACE PROPULSION

The Space Propulsion Technology Program is structured to meet future space transportation requirements for a broad spectrum of future mission applications, including planetary and Earth-orbital operations. These requirements range from very large chemical propulsion systems with hundreds of thousands of pounds of thrust to very small high specific impulse electric propulsion systems with thrusts of millipounds. Figure 4 illustrates the relative sizes of these systems. The overall objectives of this technology program are to extend our capability to economically explore the solar system and to minimize the cost of Earth-orbital space operations.

The small electric propulsion system will be used in geosynchronous satellites for station keeping replacing the chemical propulsion systems currently used. In a communication satellite application, for example, electric propulsion will allow as much as 30 percent growth in the payload weight, permitting increased satellite capability. A 20,000-hour, 5000-cycle endurance test of the one millipound ion thrust system shown in Figure 5 will continue in FY 1978. This system is a candidate for a full-scale flight test on an early Shuttle mission.

This basic engine approach may be scaled up to a 30-millipound thrust level and combined with a solar electric system as shown in Figure 8 to provide a solar electric propulsion (SEP) system. At these sizes, SEP can provide the primary thrust for planetary exploration at significantly reduced trip times. The 15,000-hour endurance test of a 30-millipound ion engine, initiated in FY 1977, will continue in FY 1978 as well as the evaluation of the power processor unit. The fabrication of one wing of a full 25-kilowatt solar array (two wings), similar to the one shown in Figure 6, is scheduled for delivery in FY 1978. This 13-by-104 foot wing, having a specific power of 30 watts per pound, is capable of producing 12.5 kilowatts of power and is being considered for test on an early Shuttle flight. In FY 1977 a program was initiated to investigate extending the performance of solar electric propulsion at higher power (up to 120 kilowatts) and lower propulsion system mass. This factor of 5 improvement could enable very high energy missions, such as a rendezvous with Halley's Comet.

Work also continues on exploring various potential applications of the ion beam technology. Experiments in the areas of sputter deposition, milling, texturing, and biomedical applications continue. A major scientific development which resulted from this research program was the demonstration that the physical process of plasma-dynamic lasing is possible.

At higher thrust levels, OAST has undertaken a chemical propulsion program to provide the technology for an advanced, high-performance planetary spacecraft retro-propulsion system. A Systems Technology program was initiated in FY 1977 with the goal of evaluating by 1980 a complete fluorine-hydrazine system as shown in Figure 7. The use of fluorine-hydrazine will increase specific impulse by 25 to 30 percent over current retropropulsion systems. This increase will enhance mission capability

or reduce the number of launch vehicle upper stages required. In FY 1978, procurement of flight-weight components will be completed and the components will be made ready for verification testing.

Another major effort in chemical propulsion is to provide the technology for future space transportation vehicles that will reduce their physical size (while maintaining payload capability), extend their life, and lower their operation cost. The focus of this work is on mixed-mode propulsion which involves the use of two fuels. (low-density liquid hydrogen and a high-density fuel such as RP-1) and an oxidizer (liquid oxygen) in one vehicle. This dual-fuel tripropellant approach reduces the amount of hydrogen required to accomplish a given mission, and therefore the vehicle size, as compared to a vehicle using only liquid hydrogen. Figure 8 illustrates the effect of the dual-fuel approach on vehicle size for a typical orbital transfer vehicle with equal payload capability. In FY 1978, technology efforts will continue in the basic areas of combustion, cooling, and heat transfer for both single- and dual-fuel engines. Also, work will be continued to extend component life and to characterize candidate high-density fuels for mixed-mode propulsion applications.

The feasibility of advanced high-thrust, high specific impulse propulsion concepts is also under study. Some of the concepts that have potential for achieving high thrust with high specific impulse (1000-5000 seconds) include atomic and metallic states of hydrogen, and gaseous fuel nuclear propulsion. Work is continuing on methods to produce and store metallic hydrogen. Recently, a new phase of experiments began in research in gaseous fuel reactors. In December, a reactor test assembly, shown in Figure 9, with a circulating gaseous uranium fuel was completed and made ready for operation. In addition to potential applications in space, the gaseous fuel reactor system may have potential for Earth-based power systems with improved safeguard features including radioactive waste annihilation by the reactor. For these reasons, ERDA has initiated a preliminary study of gaseous fuel reactors for Earth-based power plants.

OAST has also initiated an evaluation of the solar sailing concept as a potential alternate form of low-thrust space propulsion. Recent studies have indicated that the solar sail offers potential for improvements in planetary exploration capability. The solar sail, shown conceptually in Figure 10, utilizes the pressure of light from the Sun

to create a continuous force. Because light pressure is extremely small, the sail must be very large in order to achieve required thrust levels--a sail area of approximately 150 acres. In addition, it must have a very small mass to make interplanetary trips within acceptable time periods. These two conditions (large size and low weight), plus consideration of the most extreme space environments to which the sail could be exposed (high temperature and strong ultraviolet radiation at its closest approach to the Sun) have established the technology requirements which must be satisfied. There are several configurations under consideration. One, a square sail, might appear as shown on the figure when fully deployed in space. This configuration is stiffened by expandable structural members. An alternate approach is to spin the sail and take advantage of the centrifugal force to stiffen the sail and thus save weight.

The solar sailing technology program is scoped to provide the necessary information required to compare its capability with that of an advanced solar electric propulsion system. It is anticipated that by August of this year, OAST should be able to assess the relative merits of these two concepts.

SPACE MATERIALS

The primary technology concern with solar sails is the sail material. It will probably be a polymer film on the order of 1/10,000-inch thick. It must have a highly reflective coating, and have great resistance to high temperatures and strong ultraviolet radiation. In order to scope the technical challenge of building such a large structure from very thin film material, 1/10,000-inch thick, imagine, if you will, the square sail placed in a familiar portion of the City of Washington. If one corner of the sail is placed near the Washington Monument, the corner diagonally opposite will end up quite near the Lincoln Memorial. Obviously, the solar sail structure is many times larger than any NASA has attempted to deploy in space.

Another high priority area in materials is focused on advancing composite technology for space applications. Last year we described the initial progress in the program to develop 600°F composites for advanced space transportation systems. The technology demonstration will culminate with laboratory testing of a full-scale Shuttle component which can be directly compared with the current metallic component. As shown in Figure 11, the Shuttle body flap has been selected as the technology demonstration component.

Also indicated on the figure are the FY 1978 plans involving fabrication technology developments and preliminary design of the composite body flap to Shuttle requirements. The polyimides to be investigated have been selected on the basis of screening tests which determined that the material can withstand to 600°F for the required lifetime. Fabrication studies will establish the best techniques for producing a structure and provide assurance that the demonstration component can be designed to meet the load and temperature cycles required. Successful attainment of the program objectives will allow significant reductions in weight and maintenance in future space transportation systems.

STRUCTURES

The space structures program spans a wide range of activities from fundamental research through investigations of technology applications to laboratory demonstrations of advanced technology. Only a few of the many important aspects of the program are discussed here.

Efforts are underway to provide the technology needed for large space structures which can be efficiently transported to orbit and deployed or erected in space. Since that time, OAST has surveyed the potential needs for large structures between now and the year 2000. These needs represent a large variety of ultimate users of the capability provided by the large structures. This survey is, of course, only to guide our technology. It indicated that within the next decade, dish-shaped antenna structures and planar structures up to 900 feet in diameter are desired in both low-Earth orbit and geosynchronous orbits for a variety of users. The users include the Departments of Transportation, Interior, Agriculture, and Commerce. Most of these agencies would use the structures for Earth communication and resource service. Some would be used for generating power in space to permit these operations.

By the end of the century, the need for much larger structures with some being square miles in size can be visualized. The biggest of these might be used to generate power for transmission to Earth. It seems that such structures are in fact attainable but that a broad technology development program is required to attain the very large sizes, to minimize the transportation cost,

and to assure the surface precision that is required for communication and observation purposes.

Deployable structures, which can be packaged for launch in the Shuttle and automatically extended in orbit, are being investigated. An objective is to make possible launching the largest structure in the smallest package and provide for a deployed structure with the necessary dimensional accuracy and stability. An example of the possibilities being developed for deployable antennas is illustrated in Figure 12. A typical large dish antenna as shown will require a reflector surface with accuracy of a few hundredths of an inch. Previous technology studies resulted in a launch package 14 feet by 30 feet for a 100-foot diameter deployed antenna. Preliminary results of advanced technology studies indicate the potential for packaging a 300-foot antenna in the same size launch container.

Technology is being investigated for larger structures which would require multiple Shuttle flights and would need to be erected in space. In this program, the old packaging concept of "dixie cups" has been applied to develop a tapered column which is shown in Figure 13. The taper permits stacking many half columns to greatly improve the packaging density and launch efficiency. The column pictured is fabricated from graphite/epoxy composite material which provides high stiffness and thermal stability to simplify maintaining the alignment accuracy of the assembled structure. Techniques for erecting large truss structures using such elements will be studied. Work in large structures is continuing and in NASA's opinion, will be an area of great importance and high payoff in the space program.

SPACE ELECTRONICS

Turning now to our space electronics programs, NASA's current programs have been reoriented to address major technology needs. The resultant new directions for space electronics are summarized in Figure 14. With the increased payload volume anticipated for the Shuttle era, reduction in future mission support costs will become critically important. The goal is to reduce these costs by a factor of 10 (per bit of raw data) by focusing on automated operations for both Earth-orbital and planetary space systems. Increased reliance on autonomous navigation, station keeping, and maneuver control will significantly reduce tracking and mission support requirements. The

use of free-flying teleoperators and robotics will allow us to perform in-orbit inspection, assembly, maintenance and repair.

Extension of the current capability to acquire information on a global scale will require efficient data acquisition systems and precision pointing and control. Efficient data acquisition will result from development of dedicated sensors which directly monitor selected features such as crop status, and through multifunction or tunable sensors which allow observation of several parameters such as atmospheric constituents or pollutants from the same instrument. Precision pointing and control will provide systems with better than 1 arc-second pointing capability to adequately resolve surface features, control large sensor arrays, and control large structures for orientation and stabilization.

Real-time data management and low-cost data distribution concentrate on the ability to reduce and apply vast quantities of acquired data in real time at affordable costs. Emerging technologies such as charge-coupled devices, microelectronics and fiber optics permit revolutionary advances in onboard data processing, and the direct transmission of the resultant information to a wide variety of users.

Successful development of the space electronics technologies covered by these new directions in the next decade could provide this country with the space-based capability needed for global monitoring and protection of the environment, for the efficient utilization of natural resources, and for the cost-effective exploration of the solar system and universe.

Within our FY 1978 budget submission, principal efforts will focus on real-time data management because of the high potential for near-term payoff. A program, illustrated in Figures 15 and 16 has been undertaken to provide and demonstrate advanced technology solutions for near-term critical data handling problems. These include Synthetic Aperture Radar (SAR) image processing, multispectral data processing, and microprocessor-implemented digital data systems. The Synthetic Aperture Radar (SAR) used by SEASAT in the Oceanphysics program requires that the data collected be converted into images as shown in Figure 15. The SAR processor will use a digital charge-coupled device (CCD) system for real-time reduction of

radar data to images, a process that currently takes several hours of high-speed processing time for each ten minutes of observed data. A breadboard process will be built and tested with SEASAT-type data during FY 1978. This effort will be followed by a real-time ground processor in FY 1979, and an FY 1980 Shuttle demonstration of an onboard processor suitable for SEASAT, Pioneer Venus Orbiter or Shuttle imaging radar flight applications. Processing cost savings of better than forty to one over present capabilities are expected with these flight systems.

For multispectral data reduction, an analog CCD processor breadboard system, illustrated in Figure 16, will be built in FY 1978 and tested with LANDSAT image data during FY 1979. A follow-on flight system, to be demonstrated on a Shuttle Payload Flight, should permit substantial cost improvement in multispectral image classification--with costs per processed image reduced to less than \$10 compared to today's cost of about \$7000. In addition to these activities, new "computer-on-a-chip" or micro-processor systems, which can significantly simplify spacecraft onboard data management and control functions, are being developed. A prototype version of such a system will be mechanized during FY 1978 and a flight model will be validated on the Shuttle by FY 1981. Two proposed planetary missions (Jupiter Orbiter Probe and Lunar Polar Orbiter) plan to use this system if proven successful, and it is being considered for selection as NASA standard equipment. Estimated implementation costs will be one-third those of present systems.

In addition to these specific developments, the real-time data management new direction will examine long-range data processing requirements during FY 1978, and define ground and flight system design approaches and funding needs to minimize processing time and cost for planetary, applications and Shuttle missions.

The above is only a brief description of the highlights of the proposed OAST FY 1978 program. This program is exciting and contains the basic technology building blocks required for the future.

OAST SPACE BUDGET REQUEST

(THOUSANDS OF DOLLARS)

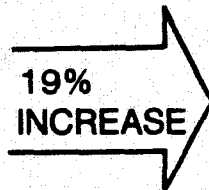
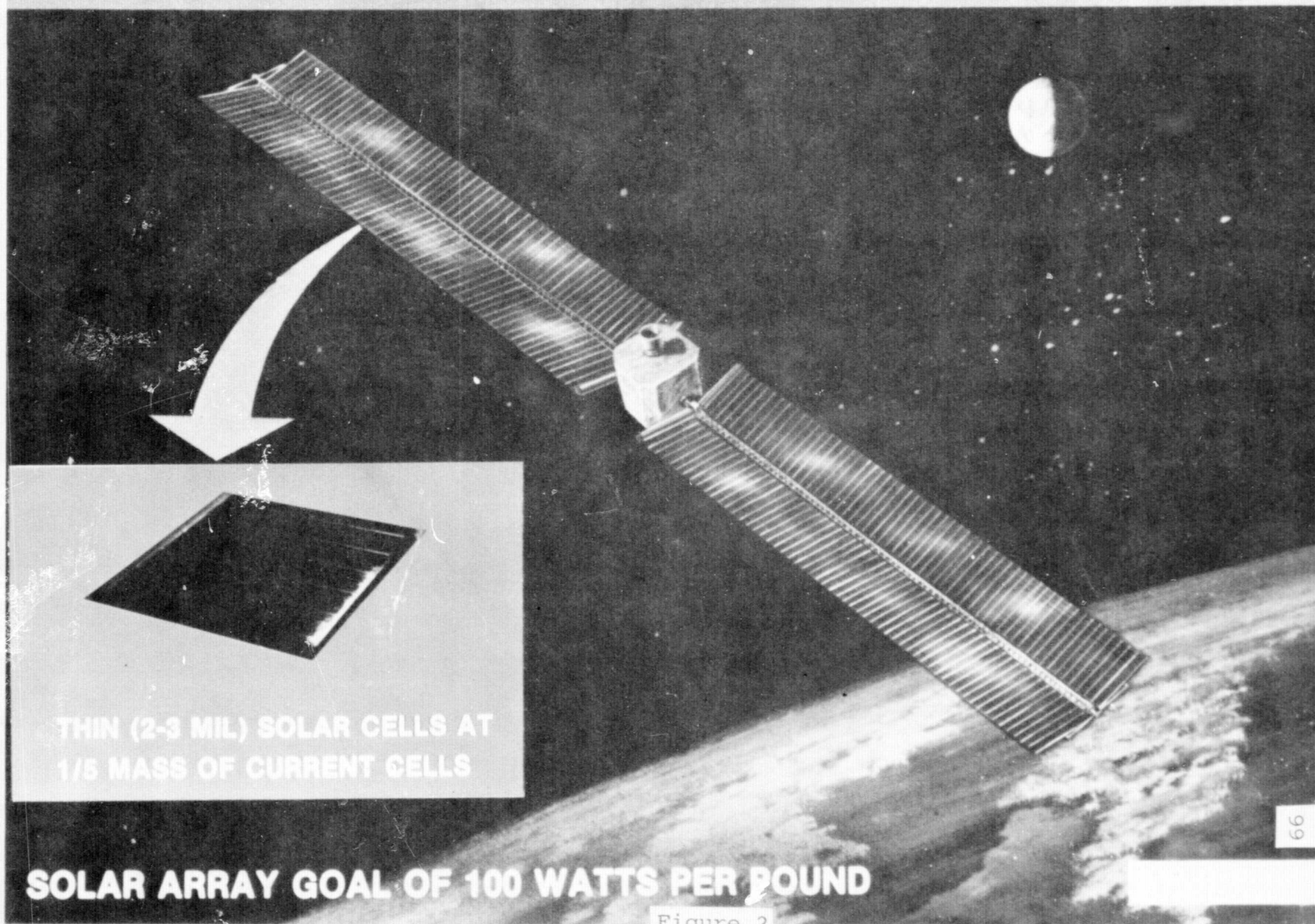
	(FY 77)		(FY 78)
<u>SPACE RESEARCH AND TECHNOLOGY</u>	<u>82,000</u>		<u>97,700</u>
R&T BASE	61,610		65,900
SYSTEMS STUDIES	2,000		2,000
SYSTEMS TECHNOLOGY PROGRAMS	3,080		5,800
EXPERIMENTAL PROGRAMS	7,010		15,000
LOW COST SYSTEMS PROGRAM	8,300		9,000

Figure 1

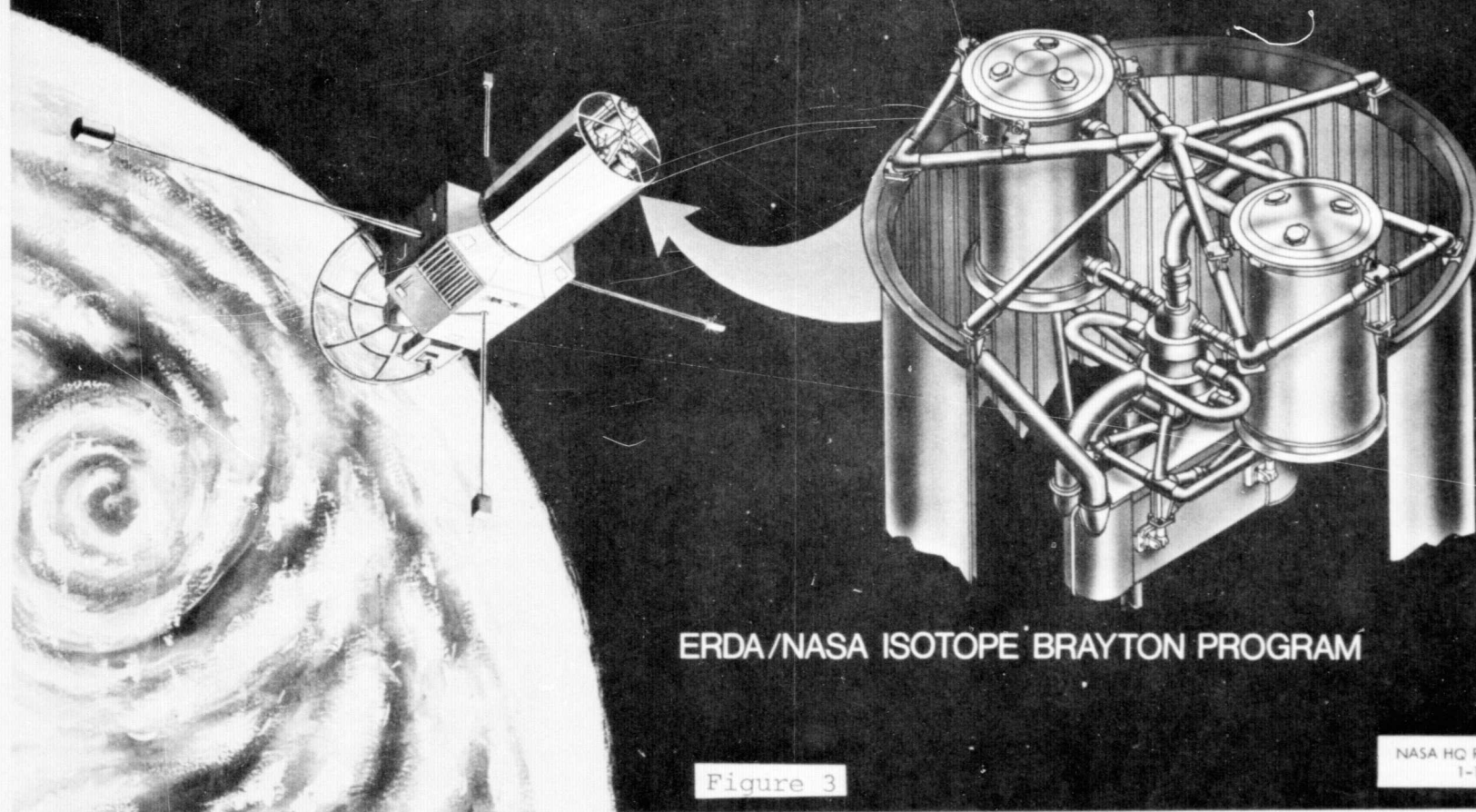
SOLAR POWER TECHNOLOGY



SPACE POWER TECHNOLOGY

THERMAL ENERGY CONVERSION

REDUCE COST AND MASS OF ISOTOPE POWER



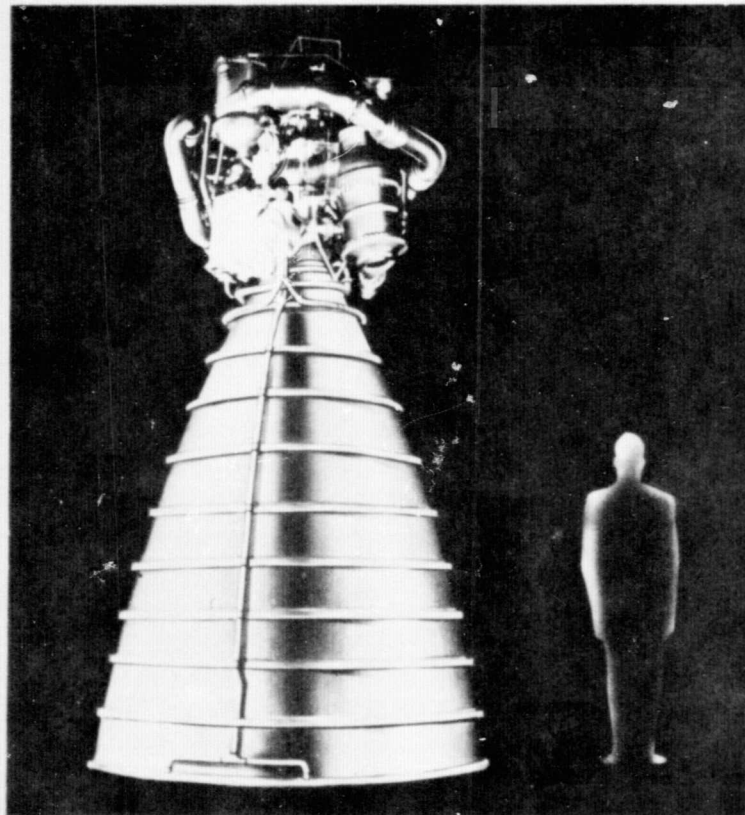
ERDA/NASA ISOTOPE BRAYTON PROGRAM

Figure 3

NASA HQ RC77-1301(3)
1-11-77

SPACE PROPULSION TECHNOLOGY

SPACE SHUTTLE MAIN ENGINE



470,000 LBS THRUST

ELECTRIC THRUSTER



ONE MILLIPOUND
(.001LB) THRUST

Figure 4

NASA HC RC77-1307(3)
1-11-77

SPACE PROPULSION TECHNOLOGY

AUXILIARY ELECTRIC PROPULSION SYSTEM

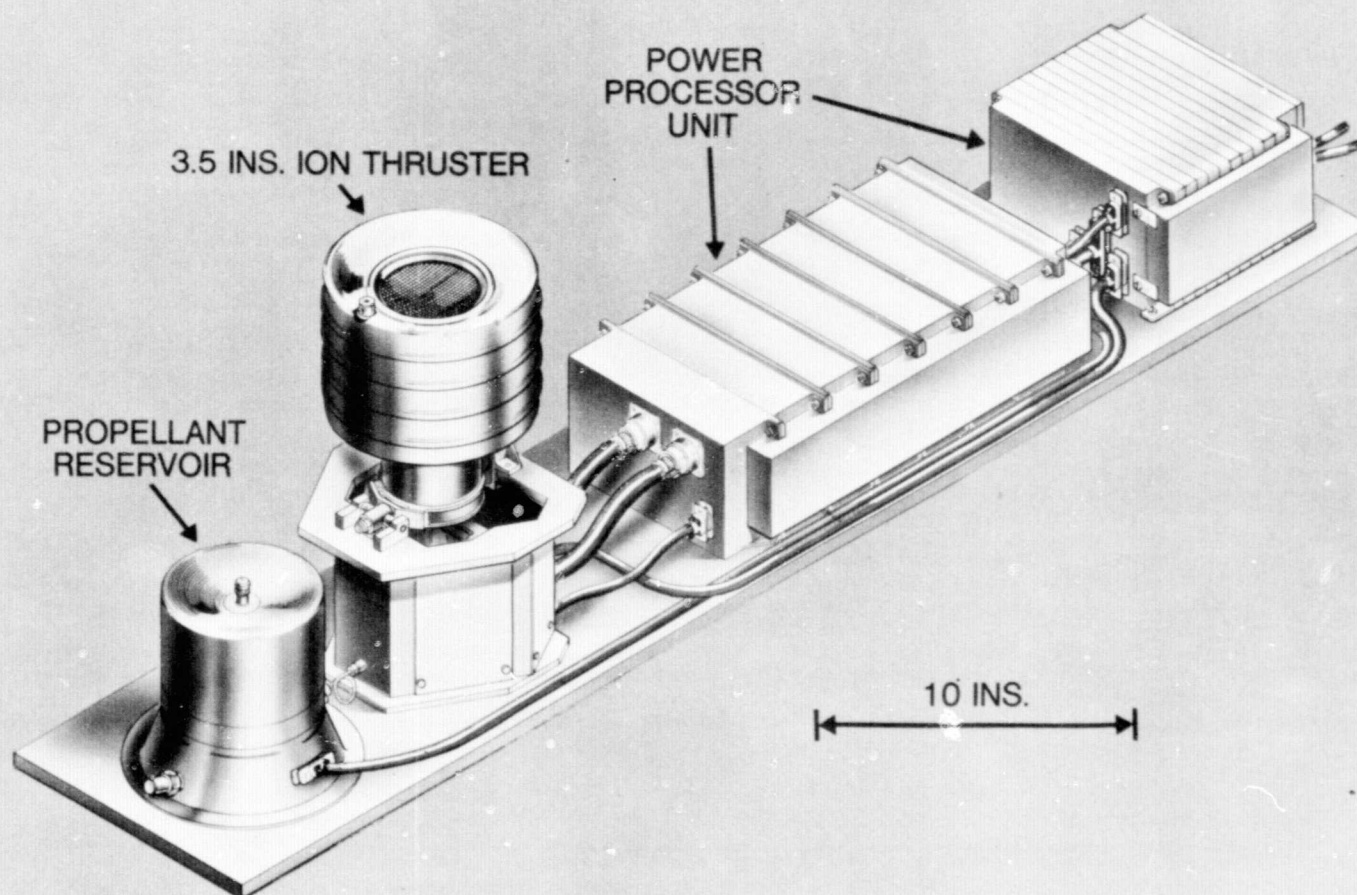
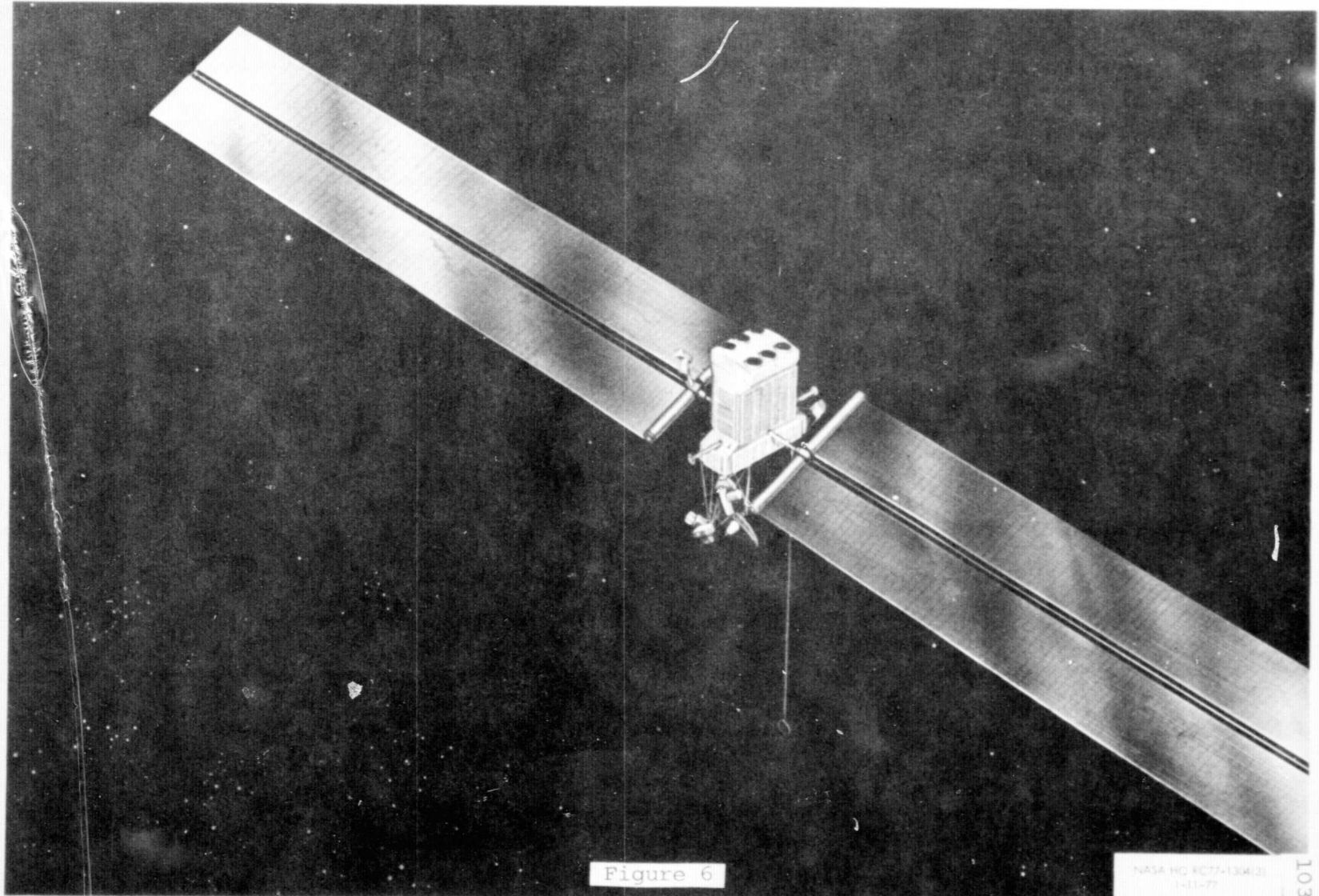


Figure 5

NASA HQ RP77-269(3)
REV-1-11-77

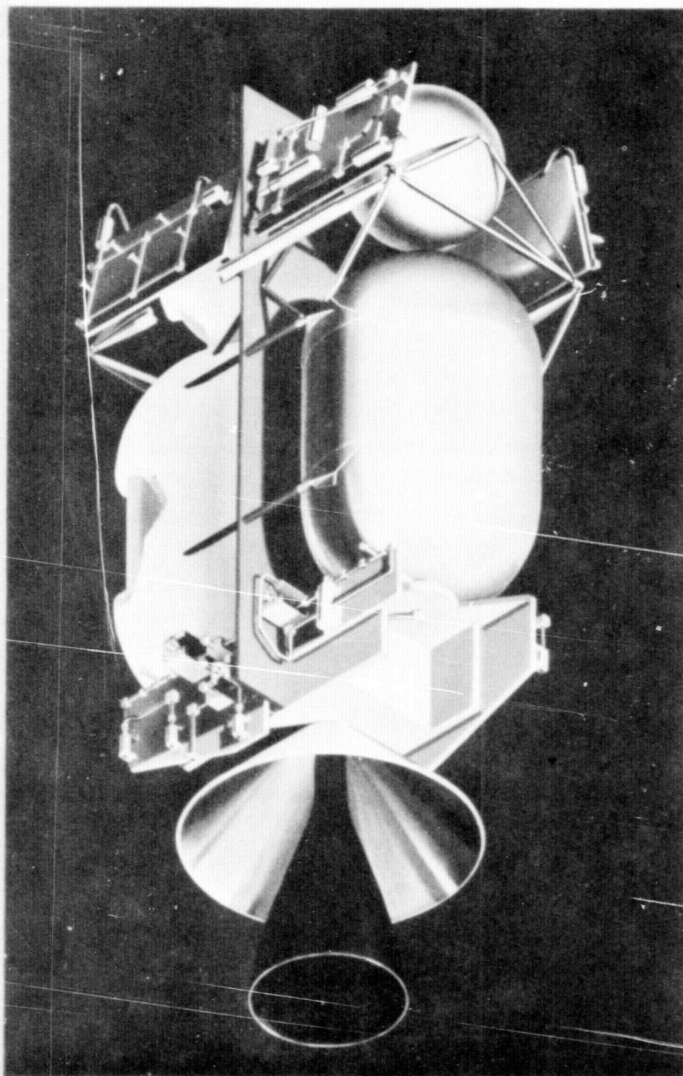
SPACE PROPULSION TECHNOLOGY

SOLAR ELECTRIC PROPULSION



SPACE PROPULSION TECHNOLOGY

FLUORINE-HYDRAZINE PROPULSION SYSTEM TEST MODULE



DESIGN CHARACTERISTICS

PROPELLANT MASS: 3080 LBS

PRESSURE REGULATED (HELIUM)

ENGINE THRUST: 800 LBS

SPECIFIC IMPULSE: 370 SEC

BURN TIME: 1 HOUR
(50 RESTARTS)

GOAL: EVALUATION OF COMPLETE
SYSTEM BY 1980

Figure 7

SPACE PROPULSION TECHNOLOGY
EFFECT OF MIXED MODE PROPULSION ON VEHICLE SIZE
EQUAL PAYLOAD CAPABILITY

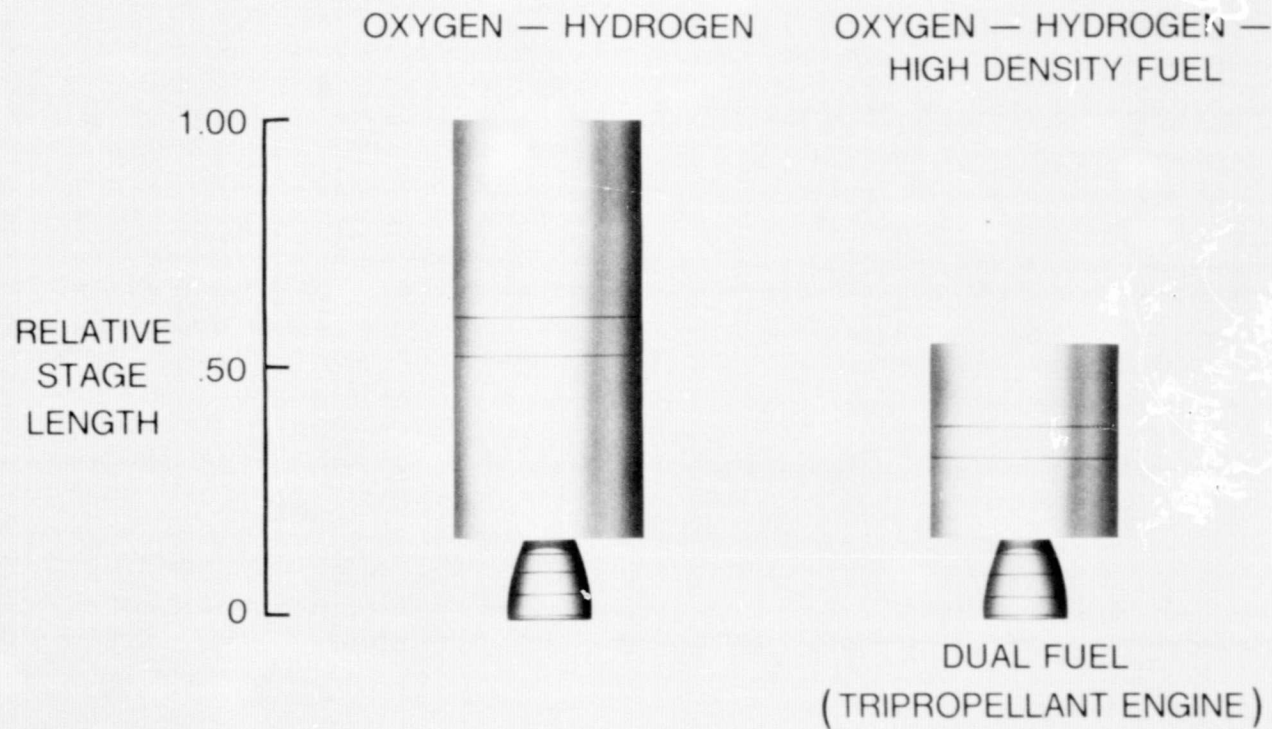


Figure 8

SPACE PROPULSION TECHNOLOGY

**UF₆ FUEL CANISTER READY FOR INSERTION
INTO CAVITY REACTOR**

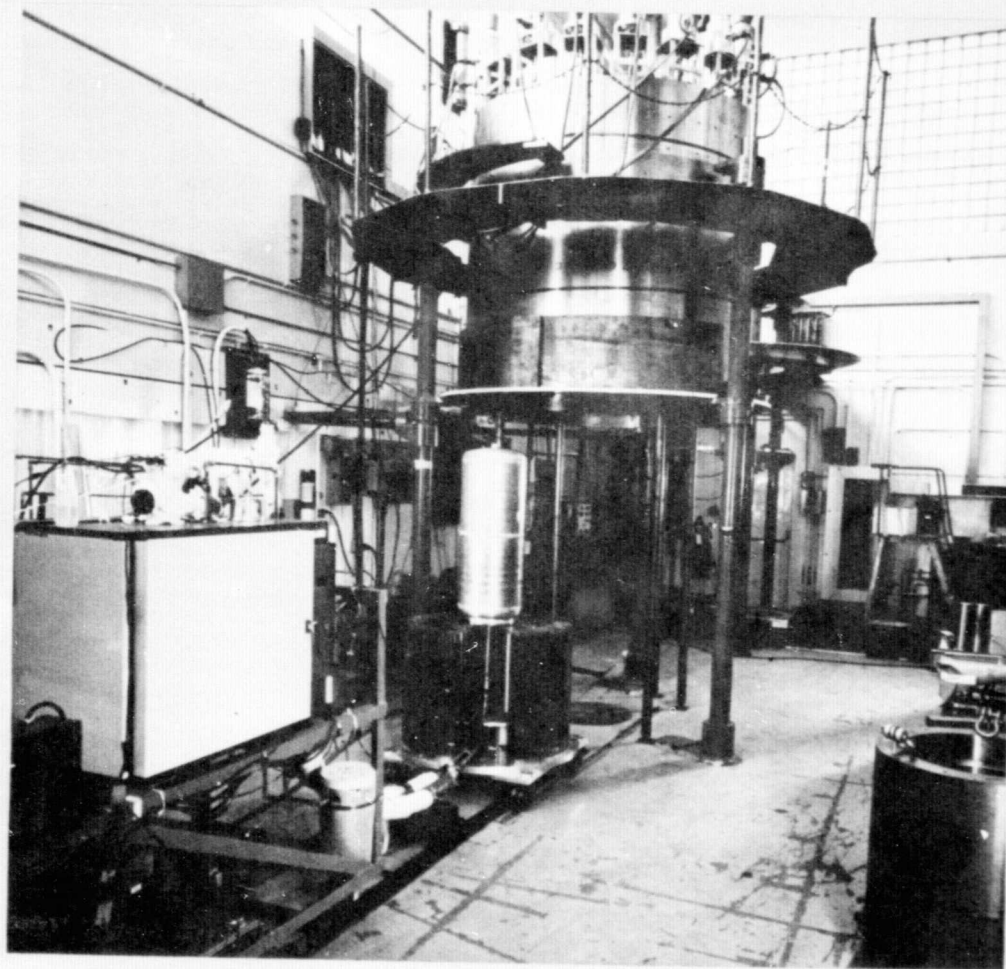


Figure 9

NASA HQ RR76-3151(3)
REV-1-11-77

SPACE PROPULSION TECHNOLOGY

SOLAR SAIL

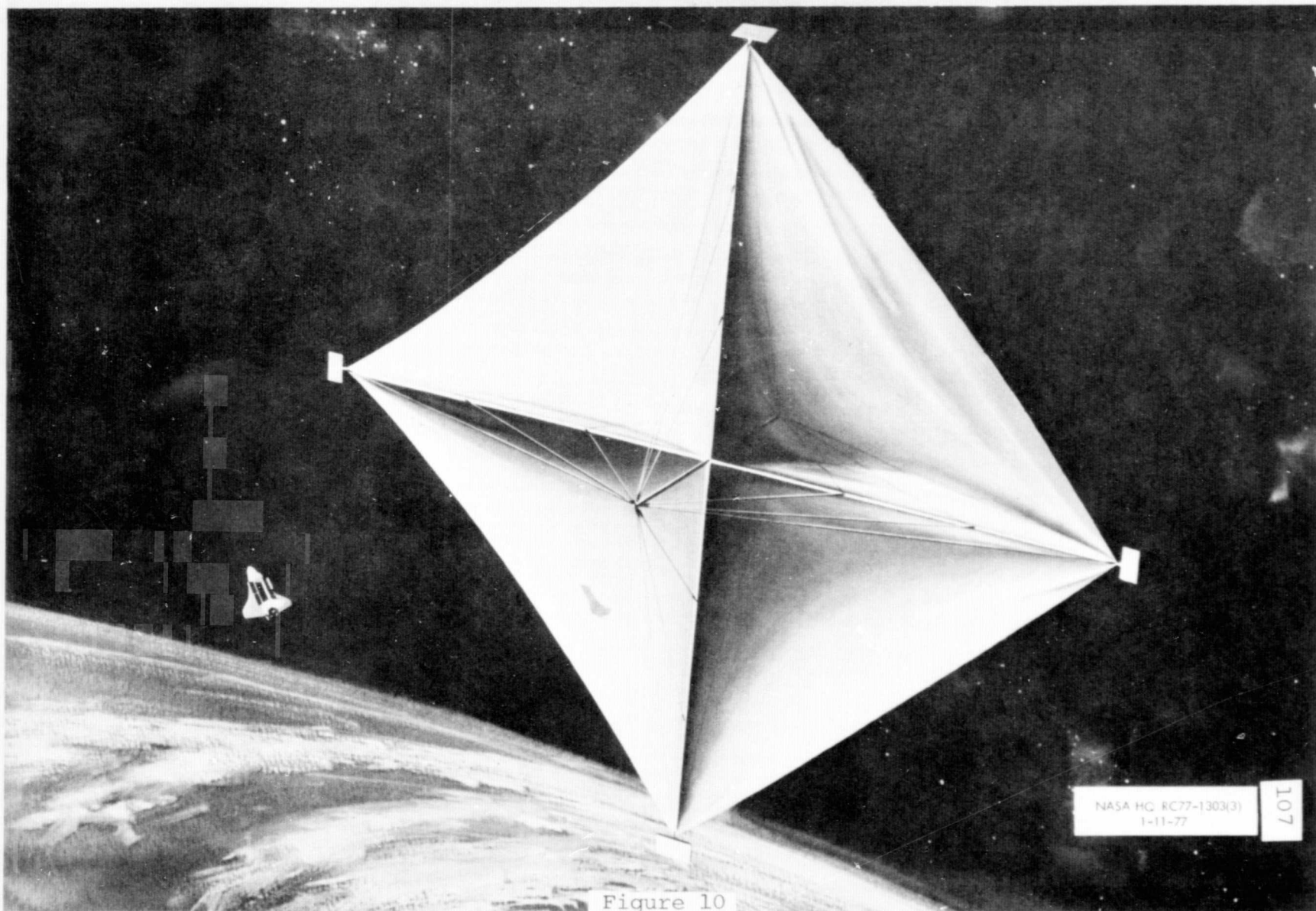
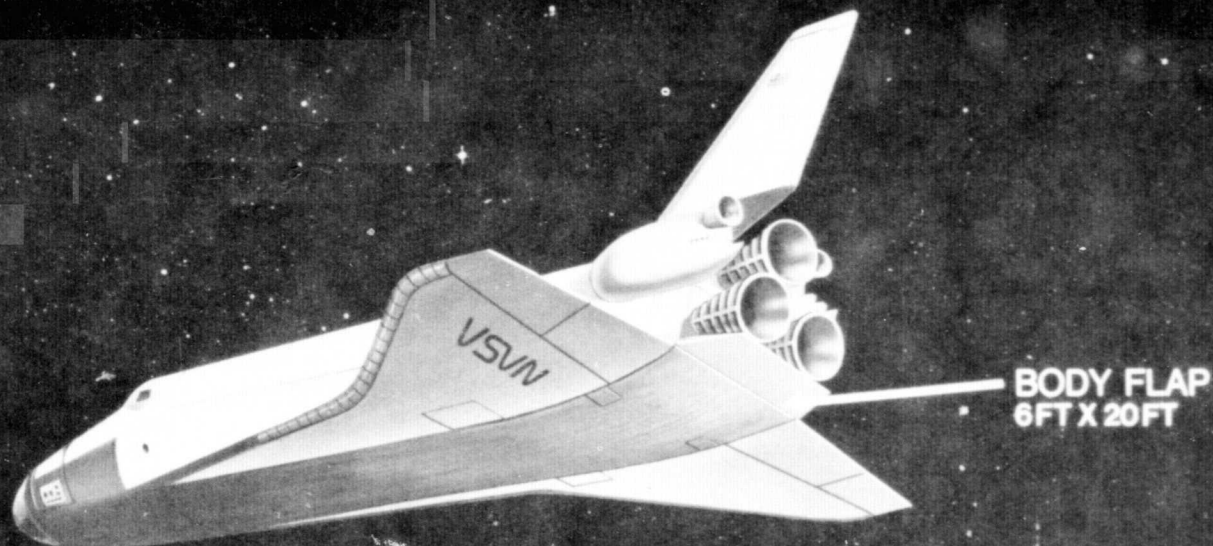


Figure 10

NASA HQ RC77-1303(3)
1-11-77

107

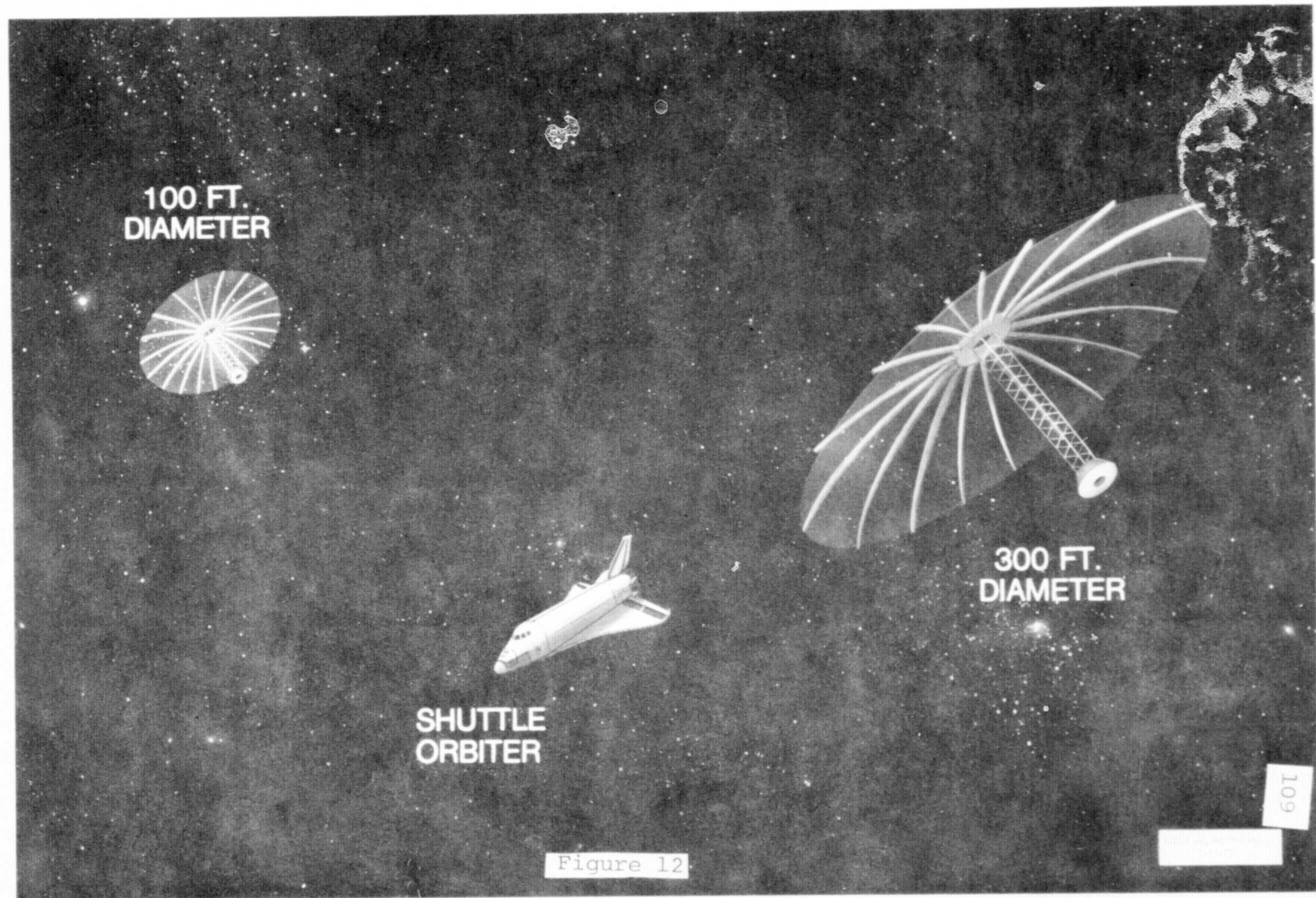
SPACE MATERIALS TECHNOLOGY
**COMPOSITES FOR ADVANCED SPACE
TRANSPORTATION SYSTEMS**



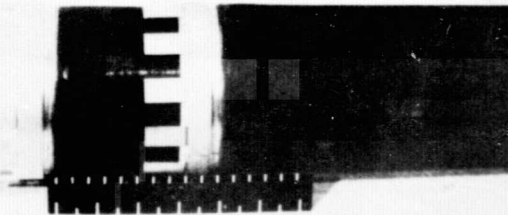
- FY 1978 PLANS —
 - FABRICATION TECHNOLOGY DEVELOPMENT
 - PRELIMINARY DESIGN & ANALYSIS

Figure 11

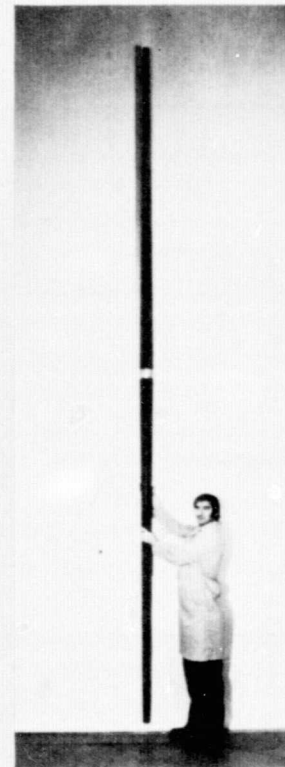
SPACE STRUCTURES TECHNOLOGY ADVANCED TECHNOLOGY FOR DEPLOYABLE ANTENNAS



SPACE STRUCTURES TECHNOLOGY TAPERED COLUMN CONCEPT



NESTED HALF-COLUMN ELEMENTS



ASSEMBLED COLUMN

Figure 13

SPACE ELECTRONICS TECHNOLOGY FOCUS

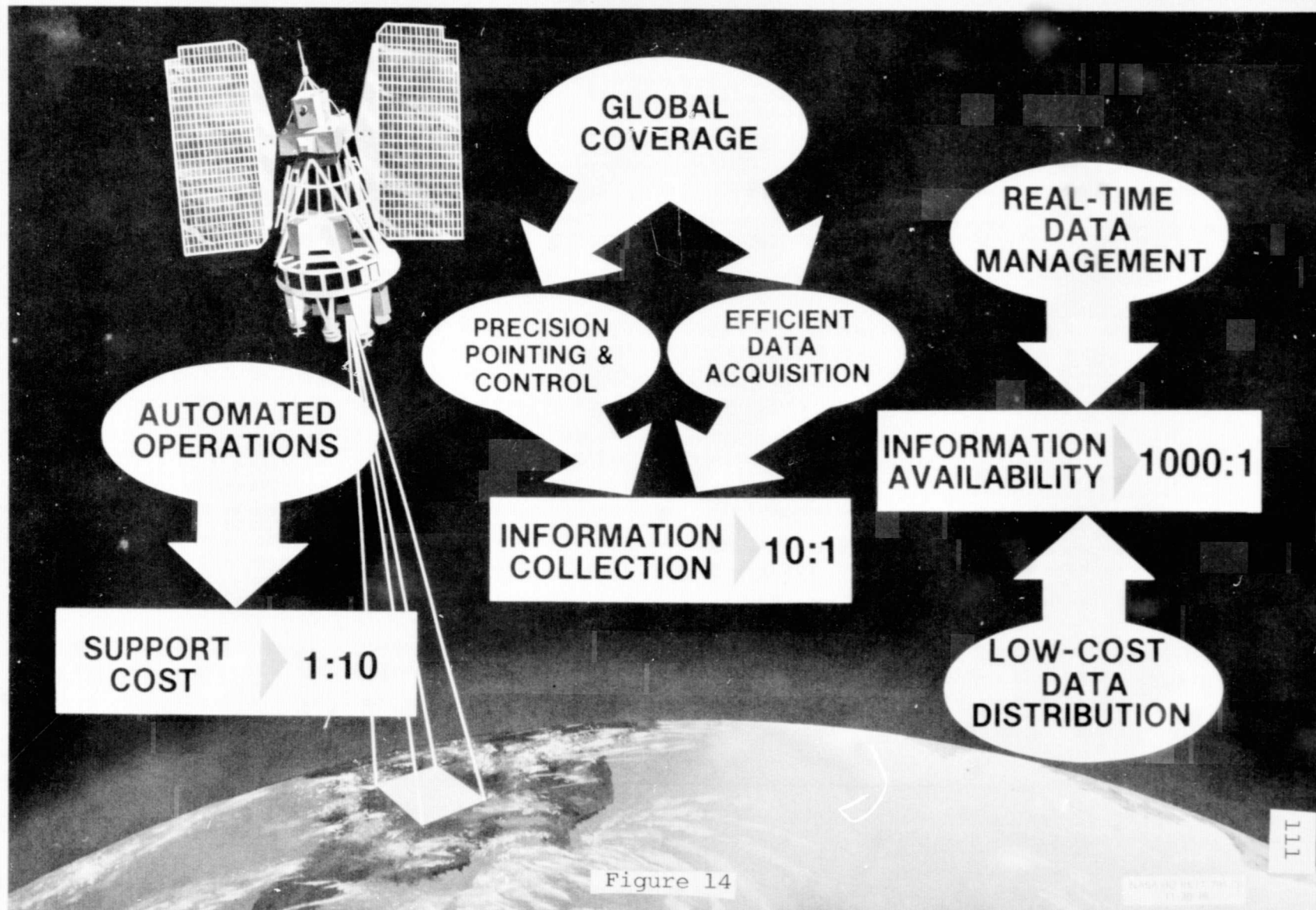


Figure 14

SPACE ELECTRONICS TECHNOLOGY

SYNTHETIC APERTURE RADAR (SAR) IMAGE PROCESSOR

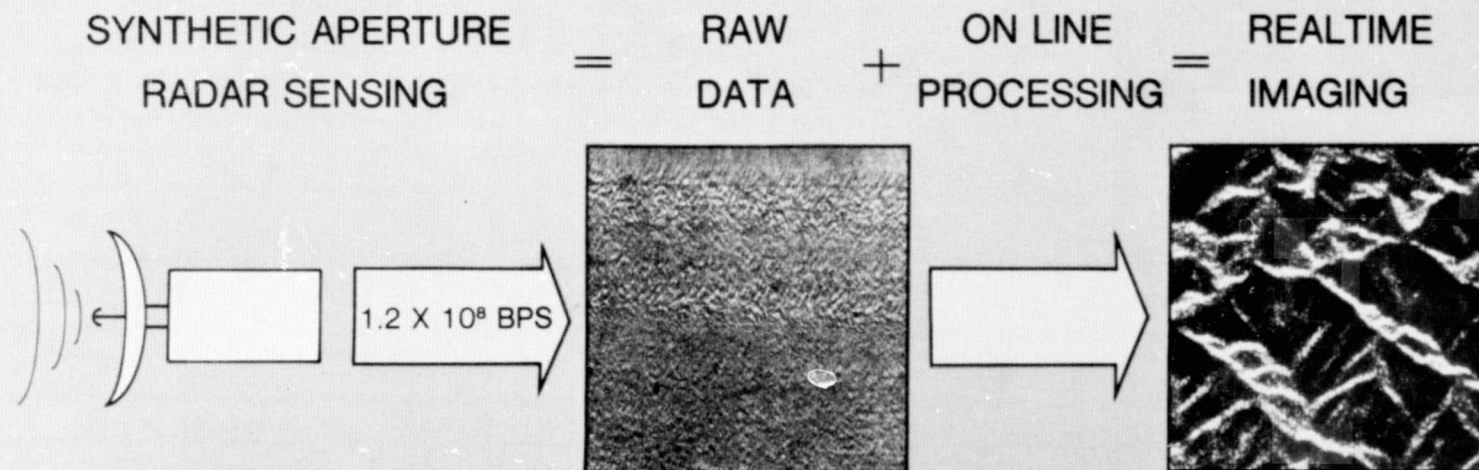


IMAGE COST REDUCTION

12,000 TO \$280

(10 MIN. RUN)

APPLICATIONS

- SEASAT GROUND PROCESSOR
- SHUTTLE IMAGING RADAR
- VENUS ORBITER IMAGING RADAR

Figure 15

SPACE ELECTRONICS TECHNOLOGY

MULTI SPECTRAL DATA PROCESSOR

MULTI SPECTRAL IMAGING

REAL TIME CROP MAP

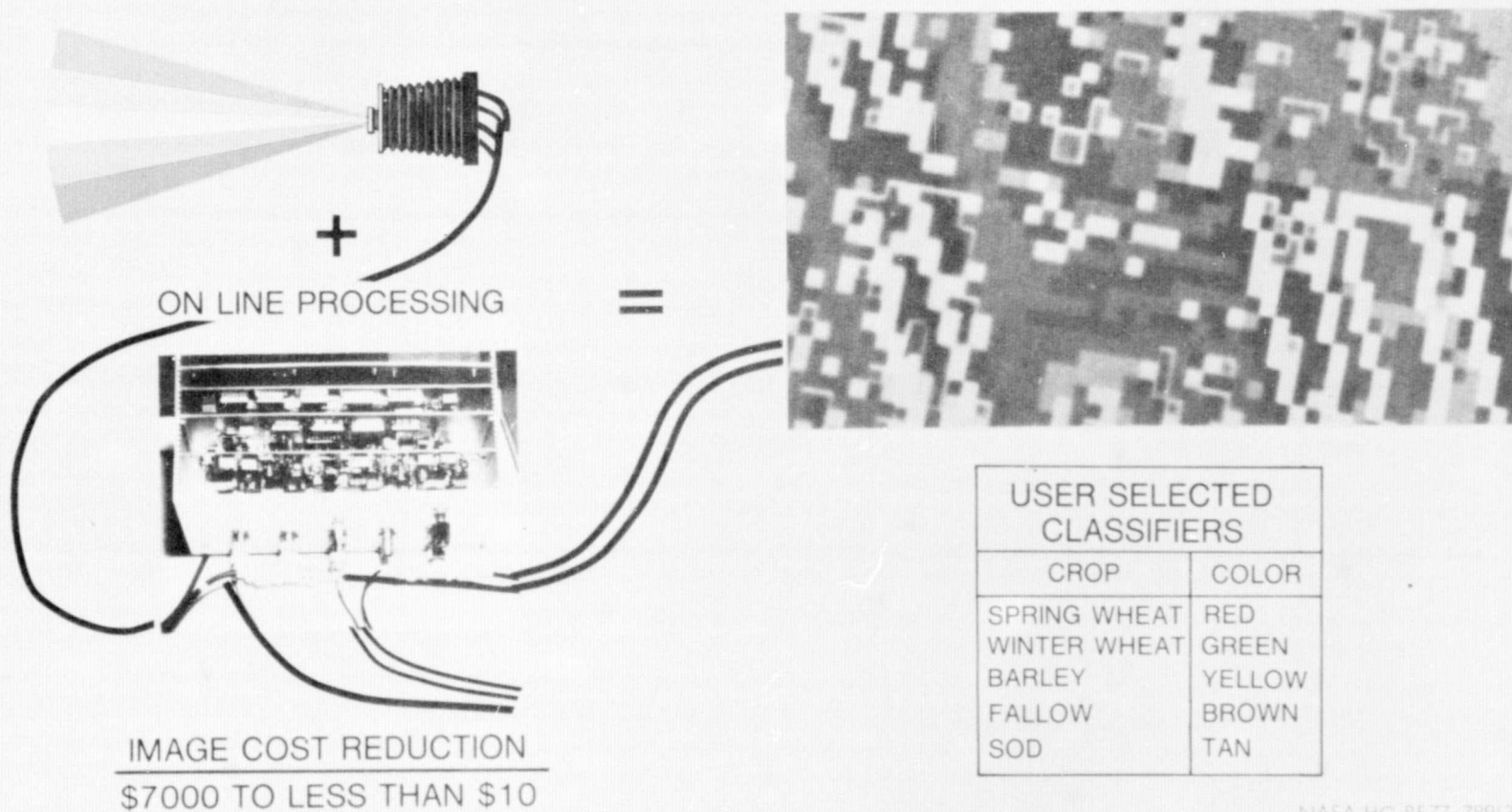


Figure 16

NASA HQ RE77-789(3)
REV-1-11-77

SECTION II-C. ORBITER EXPERIMENTS PROGRAM

The objective of the Orbiter Experiments Program is to exploit the unprecedented opportunity presented by the Space Shuttle to perform advanced research and technology investigations in the flight environment on a routine basis. The Shuttle Orbiter is an order of magnitude larger than any vehicle previously built for atmospheric entry, and with it OAST may conduct flight research in an environment which cannot be simulated either analytically or in ground-based facilities. The character of a Shuttle mission profile is such that any flight will provide opportunities for research across the full spectrum of aerospace technologies. Figure 1 depicts the several flight phases of a Shuttle mission and notes those disciplines amenable to investigation during each phase from launch (lower center) through approach and landing (clockwise to lower right).

The Orbiter Experiments Program provides the mechanism through which Shuttle-based research and technology investigations will be planned and performed. The knowledge resulting from these experiments will greatly enhance the research and technology base and will provide information to support the design of future aerospace transportation systems which may operate with increased capabilities and at lower recurring costs than the present system. The planned program consists of experiments which fall into two broad categories: (1) those which will only utilize data available from the Development Flight Instrumentation and the Operational Instrumentation to be onboard during the Orbital Flight Tests; and (2) those which will require augmentation to the onboard instrumentation. In addition to the planned program, OAST will provide for the dissemination of selected flight data to the research community for use in additional investigations.

Two examples of unique instrumentation which are under consideration to augment the Development Flight Instrumentation are illustrated in Figure 2.

First, pressure and temperature sensors would be installed in the Orbiter nose cap to provide free-stream environment and vehicle-to-stream relative attitude information over the entire Shuttle entry regime. This information will be extremely valuable from the standpoint of research in the areas of aerodynamics, aerothermodynamics, and flight controls. The development, by the Langley Research Center,

of the unique instrumentation for this experiment in itself represents a technology advance associated with failsafe penetrations of high-temperature thermal protection materials.

Secondly, an instrumentation package of research-quality rate gyros and accelerometers is presently installed in the Shuttle Approach and Landing Test Vehicle. This instrumentation package will provide vehicle inertial attitude and rate information with sufficient precision to allow flight determination of subsonic vehicle aerodynamic coefficients. Comparison of flight data from these instruments with appropriate wind-tunnel data will aid in improving the capability to predict full-scale vehicle subsonic aerodynamics. An improved, space-hardened instrumentation package, being developed for OAST by the Johnson Space Center, could fly aboard the Orbital Flight Test Vehicle as a part of the Orbiter Experiments Program. Data obtained with this instrument will complement the subsonic information, and enhance aerodynamic predictive capabilities for entry vehicles in the transonic, supersonic, and hypersonic flight regimes.

Experiments which promise to be of significant value to research in entry aerothermodynamics are illustrated in Figure 3. These experiments could provide surface temperature distributions on both the leeward and windward sides of the Shuttle Orbiter during atmospheric entry by viewing those surfaces with infrared sensors.

The leeside temperature sensing experiment, being developed by the Langley Research Center, consists of an infrared camera to be mounted within a pod atop the Orbiter vertical tail. The infrared sensor will repeatedly scan the Orbiter leeside surfaces during that portion of an entry trajectory where the Orbiter experiences significant aerodynamic heat transfer, thereby obtaining a time history of leeside surface temperature distributions. Analysis of these data will permit increased efficiency in the design of advanced leeside thermal protection systems.

The windward temperature sensing experiment, under development by the Ames Research Center, will utilize an infrared telescope to obtain Orbiter windward side temperature distributions. An observation aircraft, carrying the telescope, will underfly a portion of the Orbiter entry trajectory, providing a single surface temperature distribution for each entry. By viewing multiple flights, a time history of windward surface

temperature distributions will be obtained. Analysis of these data has high potential for improving analytical and simulation capabilities in entry aerothermodynamics.

Additional experiments are presently entering a definition phase where the specific approach required to accomplish the experiment objectives is determined. Several experiments which fit into this category are noted in Figure 4.

The Dynamic, Acoustic, and Thermal Environment Experiments seek to improve predictive capabilities in the areas of flight vehicle structural dynamics and thermal and acoustic environments. Comparison of data obtained from experiment instrumentation with present analytical predictions will provide a technology advancement in this discipline. Improved structural environment predictive capabilities relate to potential reductions in payload development costs and enhanced structural efficiency for advanced vehicles. Experiments of a similar nature are presently being conducted on prototype and experimental military aircraft.

The Flight Control Systems Experiments will provide the instrumentation necessary to investigate a number of advanced concepts in flight controls. Specific candidate concepts which are being addressed in the definition phase are flying qualities, redundancy design techniques, and in-flight gain scheduling. Technology advancements which may result from this experiment will help provide the basis for design of future flight control systems with increased reliability and lower cost.

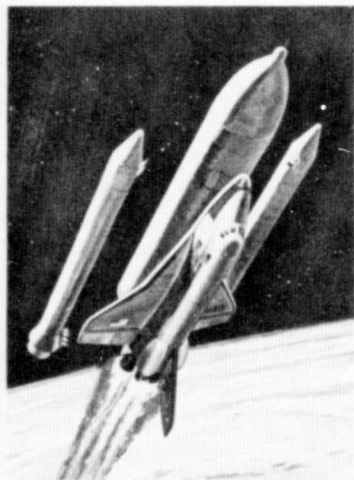
The Thermal Protection Systems Experiment will replace panels over small, non-critical surface areas of the Orbiter with instrumented panels to investigate advanced concepts in insulative thermal protection. This experiment will include investigations of high-temperature/density reusable surface insulation (RSI), flexible RSI, RSI coating repair methods, and certain aerothermodynamic phenomena associated with aerodynamic heating of thermal protection systems.

In summary, OAST has proceeded into definition and development of experiments which take advantage of the inherent operational capabilities of the Space Shuttle to perform advanced research and technology investigations on a full-scale vehicle in the flight environment. The Orbiter Experiments Program will provide the technology advancement

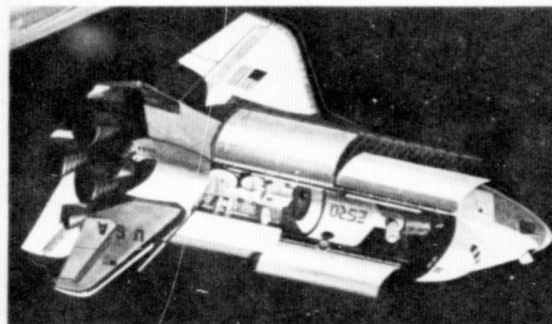
required to support the design of future aerospace transportation systems with improved capabilities and lower operational costs than the present Shuttle System. Conduct of this program will enhance predictive capabilities across all of the pertinent technology disciplines. It will also aid the assessment of the relative value of ground-based facilities.

ORBITER EXPERIMENTS PROGRAM

SHUTTLE MISSION EXPERIMENT OPPORTUNITIES



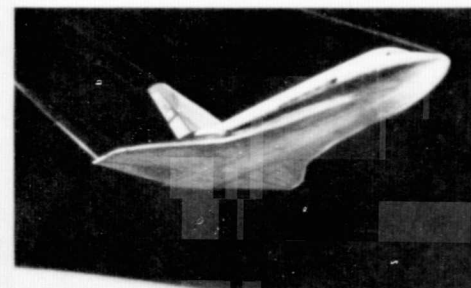
AEROTHERMODYNAMICS
STRUCTURES & MATERIALS



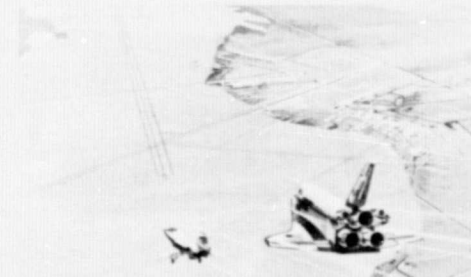
FLIGHT CONTROLS
PROPULSION



AEROTHERMODYNAMICS
PROPULSION
STRUCTURES & MATERIALS



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FLIGHT CONTROLS
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Figure 1

ORBITER EXPERIMENTS PROGRAM

ORBITER ENTRY AERODYNAMIC DATA SENSING

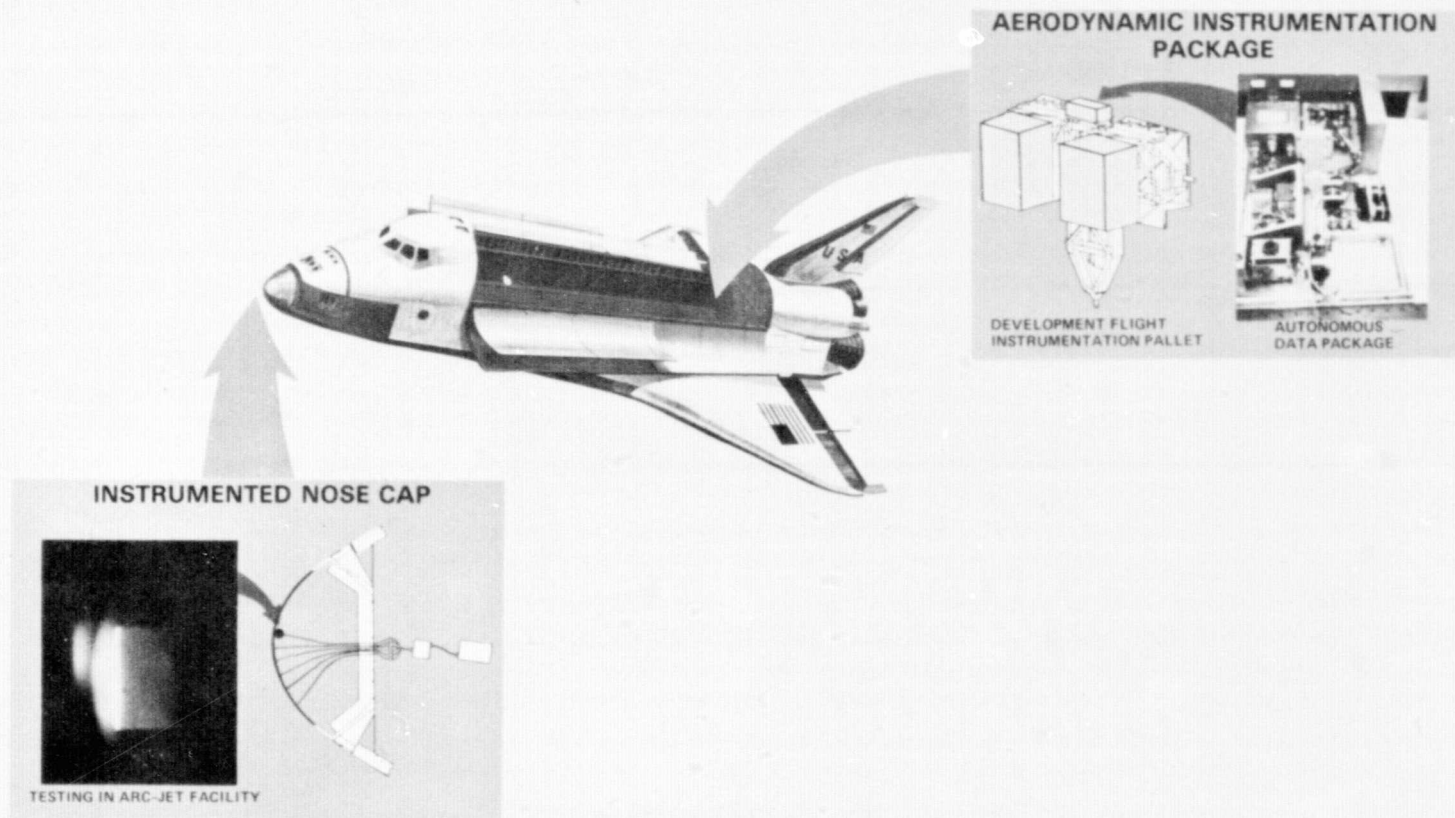


Figure 2

ORBITER EXPERIMENTS PROGRAM

ORBITER ENTRY AEROTHERMODYNAMIC DATA SENSING BY INFRARED SCANNING

